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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service • Environmental Health Service

XUM

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 10, October 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and x rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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CONTENTS

Page

REPORTS

Some Measurements on Radioactivity in Sweden Caused by Nuclear Test Explosions 487

Attilio Magi, Jan Olof Snihs, and *Gun Astri Swedjemark*

Environmental Survey of Uranium Tailings Pile, Monument Valley, Ariz. 511

Robert N. Snelling

Results of a Study of Color Television Set Assembly and Repair Workers X-Ray Safety 519

Stanley D. Savic

Elevated Levels of Cesium-137 in Common Mushrooms (*Agaricaceae*) with Possible Relationship to High Levels of Cesium-137 in Whitetail Deer, 1968–1969 527

Wallace Johnson and *Chester L. Nayfield*

DATA

SECTION I. MILK AND FOOD 533

Milk Surveillance, June 1970 533

Food and Diet Surveillance 543

SECTION II. WATER 544

XUM

CONTENTS—continued

	Page
SECTION III. AIR AND DEPOSITION	545
Radioactivity in Airborne Particulates and Precipitation	545
1. Radiation Alert Network, June 1970, *NAPCA*	546
2. Canadian Air and Precipitation Monitoring Program, June 1970	549
3. Mexican Air Monitoring Program, January–June 1970	550
4. Pan American Air Sampling Program, June 1970, *PAHO* and *PHS*	552
5. Plutonium in Airborne Particulates, April–December 1969, *PHS*	552
Surface Air Sampling Program, 80th Meridian Network, January–December 1966	554
SECTION IV. OTHER DATA	563
Radionuclides in Alaskan Caribou and Reindeer, May–December 1969, *PHS*	563
Environmental Levels of Radioactivity at Atomic Energy Commission Installations	565
1. Knolls Atomic Power Laboratory, January–December 1968	565
2. Portsmouth Area Gaseous Diffusion Plant, July–December 1969	569
Reported Nuclear Detonations, September 1970	571
Errata	572
Synopses	iii
Guide for Authors	Inside back cover

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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Some Measurements on Radioactivity in Sweden Caused by Nuclear Test Explosions

Attilio Magi, Jan Olof Snihs, and *Gun Astri Swedjemark*[1]

Data on environmental radioactivity levels in Sweden during the period 1959–1968 are summarized. Emphasis is placed on gamma radiation from the ground and concentrations of cesium-137 and strontium-90 in some foodstuffs of special interest, such as dairy milk and reindeer meat. Various empirical correlations between the concentrations of radioactivity in milk and meat and those found in precipitation are discussed; such correlations may be used in planning environmental sampling programs. The radiation dose contribution to the population due to fallout is assessed and discussed.

As a result of the large number of above ground nuclear detonations conducted in 1958, 1961, and 1962, radioactive contamination of the environment increased considerably and the occurrence of cesium-137 and strontium-90 became significant from the point of view of radiation protection. The surveillance of these radionuclides was increased by the National Institute of Radiation Protection (formerly the Institute of Radiophysics) to include measurements of the radioactivity in the air, precipitation, and foodstuffs (especially milk) and whole-body measurements. In addition, a network of ionization chamber instruments for measurement of ground level gamma radiation was established. Twenty-four instruments were geographically distributed throughout the country (*1*). A whole-body counter was also acquired in order to measure the radioactivity in human beings (*2*). The device was a complement to the ionization chamber unit constructed by Sievert (*3–5*) for quantitative total determinations, and made qualitative radioactivity determinations possible.

Fallout measurements were carried out in conjunction with other institutes. Measurements of radioactivity in meat were performed by the Royal Veterinary College; fish were analyzed by a department of the National Nature Conservancy Office; vegetables, by the Royal College of Agriculture, Ultuna; and air and precipitation, by the Research Institute for National Defense. The Institute of Radiation Protection was responsible for whole-body measurements, measurements of radioactivity in milk, and operation of the stations for measuring gamma radiation. Results from these measurements to the end of 1964 have been published earlier (*6–13*).

Although no nuclear tests series of the magnitude performed in 1961 and 1962 have been conducted above ground since 1962, the radioactive contamination of foodstuffs and radioactivity levels in human beings continued to increase until 1963–1964 but has since slowly decreased.

Fallout measurements are being continued at a reduced frequency to determine the decrease of radioactivity with time on the basis of meteorological, ecological, and biological factors, and to obtain an insight into the relationships which could arise between the radioactivity levels in different objects, places, and human beings. These data should facilitate the prediction of resulting contamination levels over longer periods in the event

[1]Dr. Magi is a hospital physicist, Department of Radiophysics, Södersjukhuset, Fack, S-100 64 Stockholm 38, formerly physicist, Special Laboratories for Environmental Research, National Institute of Radiation Protection, Fack, S-104 01 Stockholm 60. Dr. Snihs is senior physicist. Mrs. Swedjemark is a physicist, Special Laboratories for Environmental Research, National Institute of Radiation Protection, Fack, S-104 01 Stockholm 60.

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of a future increase in fallout, and also indicate sampling and protection procedures. For example, it was found that reindeer meat can be a critical foodstuff in an unfavorable fallout situation because of the particular ecology found in northern Scandinavia and the considerable consumption of reindeer meat by the residents in these regions. Therefore, the contamination of reindeer meat and the high levels of radioactivity in Lapps have been the objects for specific investigations (*14–16*).

Partial results of the measurements and calculations made by the Institute of Radiation Protection since 1965 have been published at intervals in papers presented at congresses, in annual reports, in reports to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (*17–46*) and in reports for the Nordic collaboration on these questions (*47*). The reports have usually had the form of data summaries. This paper presents results and calculations of fallout measurements up to 1969.

Methods of measurements, calibrations, and intercomparisons

Dairy milk in 3.8 liter Marinelli containers is analyzed with a 4-by 4-inch NaI (Tl) crystal and a Nuclear Data multichannel pulse-height analyzer. The counting time was normally 40 minutes for which the minimum detectable activities (2 σ background) are 0.09 g K/liter and 10 pCi ^{137}Cs/liter. Since the 6th of March 1967, the measuring time has been 80 minutes, which has given somewhat lower minimum detectable activities of 0.06 g K/liter and 7 pCi ^{137}Cs/liter. Usually, only the content of cesium-137 and potassium-40 is evaluated but during the routine standardized evaluation, attention is also given to the occurrence of other gamma-emitting nuclides, such as iodine-131 and barium-140.

Reindeer meat is measured as deep-frozen steak and corrections are made for fat and bone content. The samples (about 1.5 kg) are placed on a plate 30 cm above the NaI crystal.

Calibrations of radioactivity measurements in milk are performed with Marinelli containers containing ion exchange material with 41.3 nCi of cesium-137 (May 1962) or water with a potassium chloride equivalent of 131.0 g of potassium. The iodine-131 calibration is made in a corresponding manner. The reindeer meat measurements are indirectly calibrated by comparison with standardized samples of milk powder containing a known quantity of cesium-137 determined from Marinelli container measurements.

The strontium analyses of dairy milk were conducted according to Bryant's method (*48*) during 1963 and 1964. From the spring of 1965, Butler's ion exchange method (*49*) has been used with the modification that the chemical yield of strontium is calculated from the calcium yield instead of using strontium-85 (HDEHP-method). Since 1967 the milk samples (each 350 ml) have been dried in air and ashed. The ash is dissolved in 1 *N* hydrochloric acid and yttrium-90 is extracted from the solution with HDEHP (*50*). The error in the counting is within $\pm$ 5 percent, the error in the chemical analysis is about $\pm$ 2 percent and the calibration error is less than 3 percent. Hence, the total error in the determinations of strontium is $\pm$ 7 percent (1 sigma error).

The beta radioactivity measurements were performed with an Intertechnique low energy beta-ray counter, type RA 12 (an anticoincidence-coupled flow counter with helium-isobutane as the counting gas). The background of the counter is 0.65 $\pm$ 0.05 cpm (maximum error). The efficiency of the counter measured on standard samples is 44.2 percent for yttrium-90 and 36.6 percent for strontium-90 in equilibrium with yttrium-90.

As a check on the reliability of the results, the analytical procedures were tested by the analysis of standard samples from the International Atomic Energy Agency (IAEA). These results have compared favorably with those from other laboratories in other countries. Figure 1 shows the result for the cesium-137 measurements.

Whole-body measurements were carried out in an "open-booth" type, whole-body counter (figure 2) from 1959 till 1965 (*2*). Since 1965, the measurements have been performed in a three-crystal counter placed in a specially built laboratory made of special concrete consisting of aggregate material and cement selected for their very low radioactivity (*51–52*). The measuring errors and the calibrations have been reported in detail (*53*). A review of the measuring errors in a single in vivo measurement for both the "open-booth" and the three-crystal counter is given in table 1. The errors in the calibration and the Compton part of the spectrum are calculated from measurements on phantoms. The error in

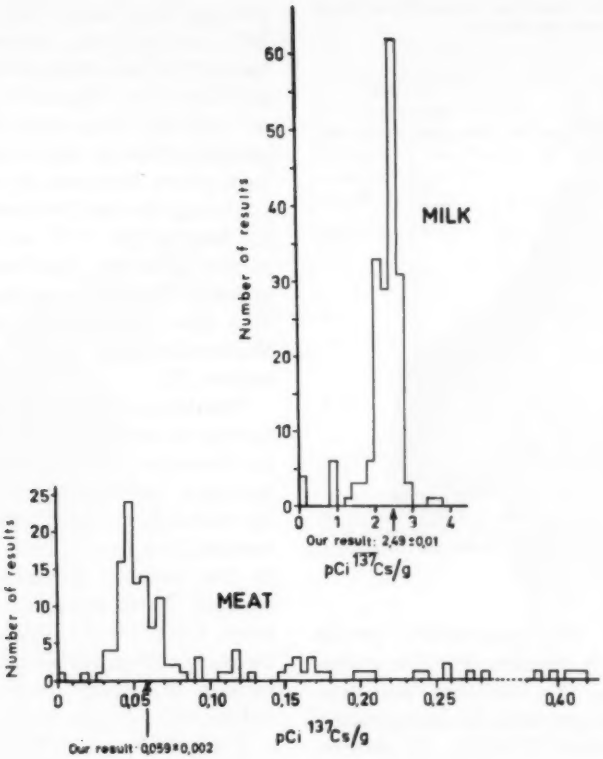

Figure 1. IAEA comparative measurements, 1966

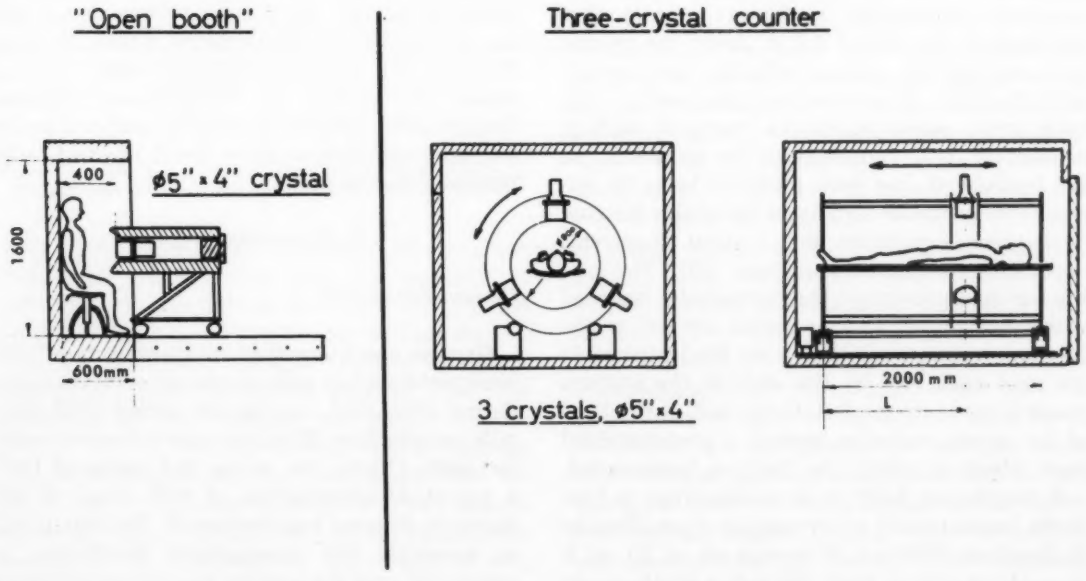

Figure 2. Open booth and three-crystal whole body counters

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Table 1. Summary of the counting errors for a single in vivo measurement[a]

Type of error	"Open-booth" counter (percent)		Three crystal counter (percent)	
	Potassium	Cesium-137	Potassium	Cesium-137
Standard deviation due to counting (σ_{stat})	4.3	5.8	5.1	6.7
Calibration error	3.6	.5	3.9	4.0
The error in the Compton part of the spectrum due to potassium in the cesium interval	—	1.8	—	1.3
The error in reproducibility	4.0	4.0		
The error due to geometry originating from differences in body constitutions	4.8	4.8	5.4	5.4
Total error ($1\sigma_{tot}$)	8.4	8.8	8.4	9.6

[a] The calculations have been made for 140 g potassium and 10 nCi cesium-137, assuming that the measuring time of the background is much greater than the measuring time of the subject (30 minutes). Bismuth-214 contamination was not considered.

the reproducibility for the "open-booth" device depends on variations in posture. For the potassium-40 measurements, the variation was estimated for a single measurement by comparisons of potassium measurements of about 20 persons in two observation series.

The measurement of the gamma radiation from the ground is made with high pressure ionization chambers constructed by Sievert (*1*, *54*). The instruments are placed 2.5 m above the ground and measure the gamma radiation continuously at 24 locations distributed over the country. The total error, consisting of the errors of reading, calibration, and variations of the sensitivity in the instrument, has been found to be ± 10 percent. The minimum significant detectable increase in the gamma radiation level is about 20 percent, depending on natural variations (*55*). The continuous measurements are automatically recorded with point writers and the results are sent to the Institute once a week. However, the instruments are read each day by the staff at the stations (usually meteorological stations) and, if the level of the gamma radiation exceeds a predetermined level (about 60 μR/h), the Institute is contacted.

A continuous check on air radioactivity is kept at the Institute with an air monitor (type Frieseke & Hoepfner FH59A). It pumps air at 20 m³/h (4 m above ground level) through a continuously moving filter band. This filter band passes two beta counters, one with optional delay. Gamma spectrometrical measurements can be performed with the 4-by 4-inch NaI crystal and multichannel analyzer, previously described, for qualitative investigations of the whole or parts of the filter band where increased air radioactivity is observed.

During the last few years, the air radioactivity has been so low (with one exception) that the beta results have not significantly varied from background. Gamma spectrometrical measurements of a few arbitrarily chosen filter samples have shown significant peaks only on beryllium-7 and cesium-137.

Precipitation measurements have been performed in such a way that it has not been possible to determine quantitatively and with any great accuracy, the total radioactivity deposited during the sampling period. Instead, the aim of the measurement has been to detect any significant increase in the activity deposited and its qualitative changes. Measurements are usually made once a week, but if results from other equipment within Sweden or from abroad should indicate a possible increase in activity, more frequent checks on the radioactivity in precipitation can be made.

Precipitation is collected immediately outside the Institute's building in a 10-liter plastic bottle placed at the bottom of a funnel formed by a 2 m² plastic cloth. If no precipitation falls, or if the bottle is not full, the plastic cloth is rinsed with tap water until the 10-liter bottle is filled. Of these 10 liters, 3.8 liters are analyzed with the 4-by 4-inch NaI crystal and multichannel analyzer. Precipitation samples are usually analyzed on the day after sampling to allow the short-lived radon products time to decay.

Radioactivity in food

Cesium-137 in milk

Gamma spectrometrical measurements of milk were performed on milk powder from two factories during 1958–1963. During the period 1962–1964, milk samples from 32 dairies were measured once a fortnight. During the winter and spring of 1965, a nationwide investigation of milk from all 292 dairies in Sweden was conducted. The intent was to determine the geographical distribution of cesium-137 over the country and to investigate the

possibilities of decreasing the number of sampling locations while increasing the sampling frequency and still maintaining the degree of preparedness.

Figure 3 (including Norway) (*56*) shows that the cesium-137 content varies regionally depending on the quantity of precipitation, among

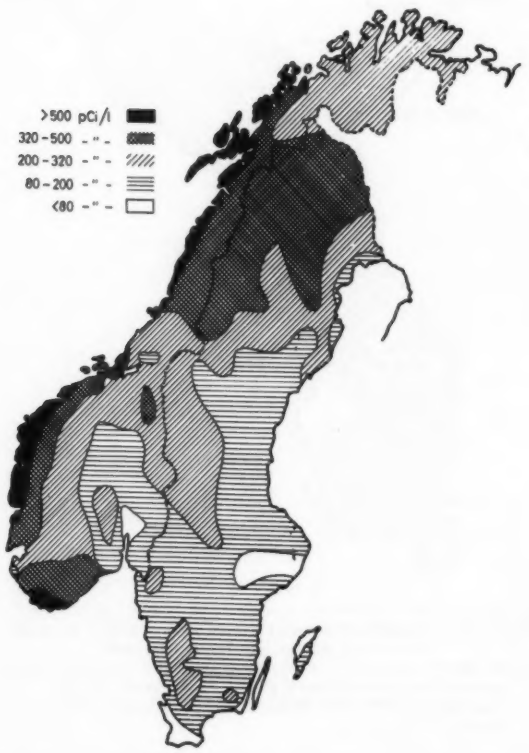

Figure 3. The geographical distribution of the cesium-137 concentration in diary milk, February-May 1965

other things (figure 4). The ratio between the cesium-137 concentration and the quantity of the precipitation during the preceding year is shown in figure 5. The ratios varied between 0.1 and 0.3 pCi/liter of milk per mm of precipitation/a for large agricultural regions, while for other regions the variation was greater (up to 0.7 pCi/liter of milk per mm of precipitation/a). The difference in the annual precipitation between these two types of regions is less than a factor of 1.5 and the difference in the ratios must principally be explained by differences in soil, fertilization, pasture, winter food, etc (*17*).

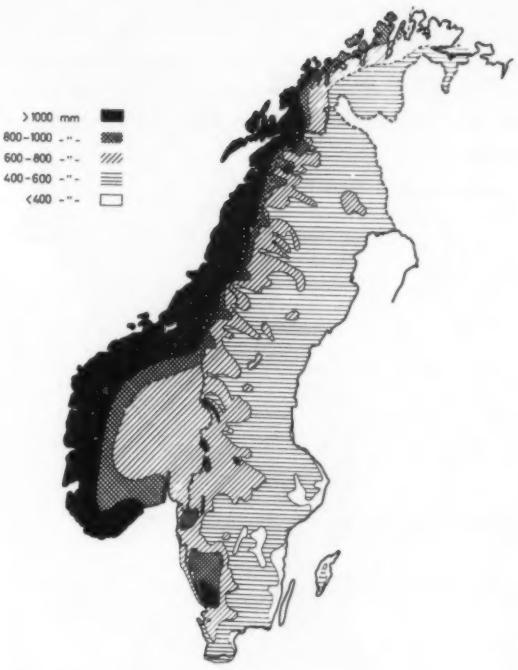

Figure 4. Total precipitation during 1964 (the isohyets for Norway are schematic)

Figure 6 shows the distribution of cesium-137 in crops and milk that can be expected from uptake from the soil as calculated by Fredriksson and Eriksson (*57*). The calculations are based on results of extensive tracer experiments with fission products and from investigations on the cesium-137 content in vegetation and milk. Figure 5 and figure 6 are based on different assumptions. The calculated values in figure 6 refer only to uptake from the soil. The observed ratios (milk concentration/precipitation) in figure 5 depend to a large extent on direct contamination of the fodder. Other influencing factors are imported fodder, the time distribution of the precipitation, etc.

On the basis of the results of the nationwide investigation, four large dairies (filled circles in figure 7) were chosen to provide the basis for the calculation of the nationwide average cesium concentration, and eight additional dairies were selected to check that the geographical distribution remained unchanged. In figure 8 the cesium concentration is shown as a percent of the nationwide average as a function of time. A seasonal variation

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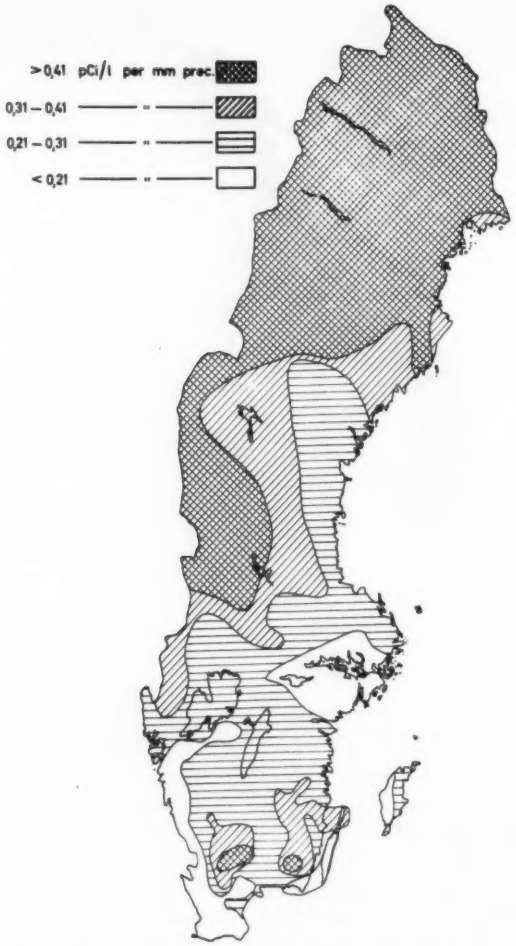

Figure 5. The geographical distribution of the ratio between the cesium-137 concentration in dairy milk during February–May 1955 and the total precipitation during 1964

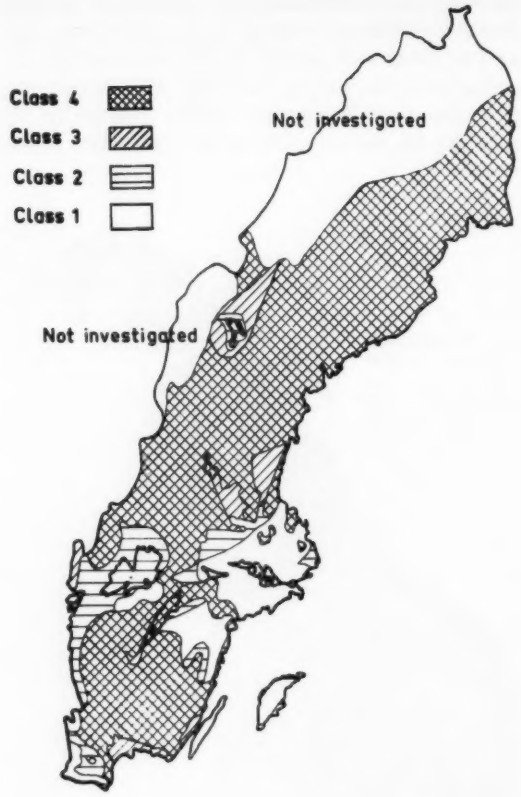

Figure 6. Anticipated content of cesium-137 in milk as a result of uptake from the soil (The land has been classified in four classes, 1–4, according to increased plant availability of the nuclides—after Fredriksson and Eriksson (57))

can be established. The dairy N (Nässjö) increased in comparison to the nationwide average from the calculated 120 to 200 percent, an average increase during the whole period of 50 percent. The other dairies, with the exception of the small mountain dairies, have decreased in comparison to the nationwide average with an average decrease of 10–80 percent during the period, 1965–1968. The dairy N is included in the calculation of the nation-wide average. If dairy N is excluded, lower nationwide averages (4–37 percent lower) are found for 1965 to 1968. Negative deviations from the nationwide averages are small while the positive ones are more pronounced. In the positive deviations, a trend to a continuous increase is found, while the negative ones show random variations. This can reflect differences in the soil, fertilization, etc, as the cause of the differences in the decrease of the cesium concentrations with time. The above mentioned facts and the poor agreement between cesium in milk and beef (page 496) suggest that the calculated nationwide averages are somewhat high. The results of the cesium-137 measurements are shown in figure 9, where the nationwide average, the dairy having the lowest content of cesium-137, and the one having the highest content have been indicated.

The analysis of milk also includes a determination of the natural potassium content. The average

Figure 7. Map of Sweden showing the sampling dairies and regions for meat sampling

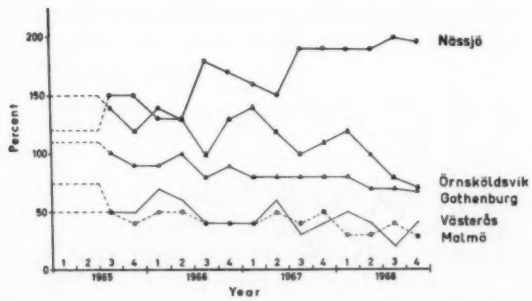

Figure 8. The cesium-137 content in dairy milk as a percentage of the nationwide average (Ornskoldsvik not included in average calculation)

for the samples taken during the summer months, June–October 1965, is 1.528 ± 0.003 g K/liter and during the winter months, November 1965–May 1966, 1.594 ± 0.003 g K/liter, where the stated errors are the standard error of the mean. A significant decrease of the potassium content during the summer months is obvious. On the other hand, no geographical variation of the potassium content could be established.

Figure 9. The cesium-137 content in dairy milk

Strontium-90 in milk

Since July 1965, analyses of the strontium-90 content of one milk sample per month from each dairy are normally made. The average calcium content in milk is 1.189 ± 0.009 g Ca/liter (1-sigma error) calculated from data from the National Dairies Laboratory during September 1961–August 1962. No geographical variation nor any significant seasonal variation could be established.

The results of the strontium-90 measurements are shown in figure 10. The curves for each of the 12 dairies have been normalized so that the mean level during the period, July 1965–May 1968, coincide with the nationwide average during the same period. The remaining differences show deviations of the time patterns and the random variations. All the curves are contained in the area bounded by the grey curves around the heavy curve representing the nationwide average.

The nationwide average for the strontium to calcium ratio has not been weighted for the milk production. The small mountain dairies were included in the calculation of the arithmetical mean shown in figure 10. Excluding these dairies results in a mean value 84 percent of the mean shown in figure 10. If the same calculation is per-

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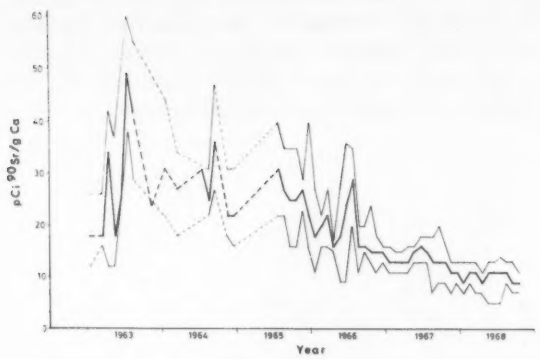

Figure 10. The content of ^{90}Sr/g Ca in dairy milk (The curves from 12 dairies have been normalized to the same level as the nationwide average)

formed for the cesium-137 content, a mean value 43 percent of the mean for all stations is determined. The geographical variation of the strontium to calcium ratio is consequently much smaller than that of the cesium content. The variation with time is also smaller for the strontium to calcium ratio than for the cesium content in milk. Figure 11 shows the strontium to calcium ratio and the cesium content in milk as a percentage of the level that occurred during the summer of 1963. The diagram indicates that during the winter of 1965, the two curves deviated so that the cesium content decreased faster than the strontium content. This would also cause a decrease of the cesium to strontium ratio.

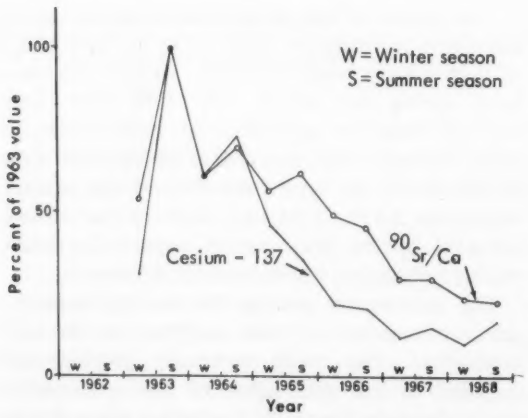

Figure 11. Cesium-137 and strontium-90 to calcium ratio as a percentage of the 1963 value

The ratio between cesium-137 and strontium-90 in milk

The cesium to strontium ratio has been calculated as the ratio between pCi cesium-137 per gram potassium and pCi strontium-90 per gram calcium. As already mentioned, the cesium to strontium ratio for milk varies geographically and with time. Figure 12 shows the time patterns for ten dairies from large agricultural regions for 1958–1968. The ten curves are normalized to the nationwide average. For 1959–1962, the curves were derived from samples of dried milk from two factories with the result that the ranges of values during that period are small. All the curves in figure 12 are contained in the bounded area around the heavy curve representing the nationwide average. Therefore, the bounded area represents both the random variation and the variations in the time patterns from dairy to dairy. The diagram shows that the time patterns for the "normal regions" in the country are quite similar. During years with fresh fallout, the summer values were higher than the winter values; this has also been found to be the case during 1967 and 1968. Peaks occurred for the nationwide average until the summer of 1964. Since then the averages have decreased until 1967 and 1968 when they were practically the same. For single dairies the ratios have increased by about 15 percent (four dairies) during the summer season.

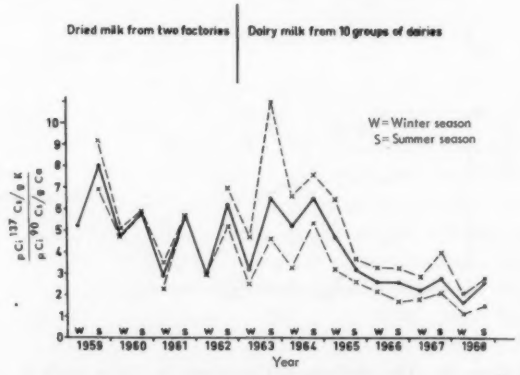

Figure 12. The ratios of ^{137}Cs/^{90}Sr (The curves from 10 groups of dairies have been normalized to the same level as the nationwide average)

The geographical variation of the cesium to strontium ratios, illustrated in figure 13, shows winter and summer averages for seven dairies from

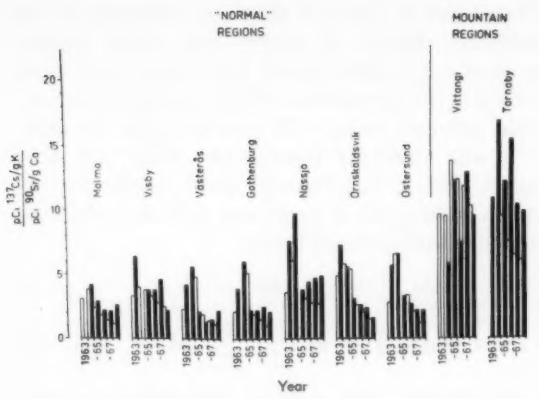

Figure 13. The $^{137}Cs/^{90}Sr$ ratios for eight of the sampling dairies
(Dark columns represent summer seasons; white columns, winter seasons)

"normal regions" and for two dairies from mountain regions. The latter values are not only higher than the values from "normal regions" but the variations over a period of years as well as the seasonal variations are also different.

Correlations of milk levels to fallout levels

It has been shown (*11*, *13*) that an equation of the following type satisfactorily gives the relationship between the mean annual cesium-137 concentration in Swedish milk and the cesium-137 deposited during 1962–1965, as reported by Lindblom and Bernström[2] (*58–61*). The calculated value has been within 0.91 ± 0.13 times the observed values.

$$\overline{m}\,(i) = a\,F_r(i) + b\,F_r(i-1) \quad \ldots (1)$$

where

$\overline{m}\,(i)$ = the mean cesium-137 concentration in milk for the year i (pCi/liter)
$F_r(i)$ = total annual cesium-137 deposition in the year i (mCi/km² · year)
$F_r(i-1)$ = total annual cesium-137 deposition in the year $i-1$ (mCi/km² · year)
a and b are constants.

However, during the years 1966 and 1969, the calculated value of cesium-137 in milk has been only one half to one third of the observed values.

During these years, the cumulative deposition reached its maximum and it would seem that equation 1 gives a good correlation for relatively fresh fallout only.

This was also found to be the case for the following equation (*62*)

$$\overline{m}\,(i) = p_r F_r(i) + p_l F_l + p_d F_d \quad \ldots (2)$$

where

$\overline{m}\,(i)$ and $F_r(i)$ have the same meaning as above
F_l = deposition of cesium-137 in the second half of the previous year (mCi/km²)
F_d = cumulative deposit of cesium-137 (mCi/km²)
p_r, p_l and p_d are described as "rate", "lag-rate" and "soil" proportionality factors, respectively, expressed in pCi/liter per mCi/km².

This relationship with $p_r = 3.0$, $p_l = 6.0$ and $p_d = 0.03$ (derived for the United Kingdom by Bartlett) gives levels which, for the period 1962–1966, are about 61 ± 10 percent of the observed Stockholm values for dairy milk. If data from the years 1967 and 1968 are included, the corresponding values are 52 ± 23 percent. The corresponding percentages for the nationwide averages are 39 ± 10 percent and 36 ± 18 percent, respectively. If Bartlett's constants are multiplied by 1.6, equation 2 results in levels close to the observed ones for Stockholm except those for 1966, 1967, and 1968, where the calculated levels were only 3/4, 1/2, and 3/4, respectively, of the observed ones.

Data for strontium-90 in milk are not expected to satisfy an equation of the same type as equation 1 derived for cesium-137, since the value for the cumulative strontium-90 deposit has a substantial influence on the result. However, since a term for the cumulative deposition is included in equation 2, this equation may also apply for strontium-90 if proper values of the constants are chosen.

In the UNSCEAR report of 1966 (*63*) equation 3 was suggested for milk consumed by the world's population.

$$C(t) = p_d F_d(t) + p_r F_r(t) \quad \ldots (3)$$

where

C = $^{90}Sr/Ca$ ratio in milk at time t

[2] B. Bernström, personal communication.

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F_d = cumulative mean deposit of strontium-90 in soil in mCi/km²

F_r = mean annual fallout rate of strontium-90 in mCi/km² · year at time t

p_d and p_r = proportionality factors also referred to as "soil" and "rate" factors.

The strontium deposits were derived from cesium-137 measurements, assuming that the cesium-137/strontium-90 ratio in fallout is 1.7 for 1958–1961 and 1.5 for 1962–1966, as reported by UNSCEAR in 1962 and 1966 (*64*, *63*). The strontium levels in milk calculated with p_d = 0.3 and p_r = 0.8 (the values suggested by UNSCEAR for milk consumed by the world's population) fall within the extreme limits of 91 ± 80 percent of the observed levels up to 1969.

For comparison, equation 2 was used with p_r = 0.70, p_l = 1.13 and p_d = 0.11 (derived for the United Kingdom by Bartlett (*62*)). The values fall within the extreme limits of 60 ± 17 percent of the observed levels up to 1969. If these constants are multiplied by 1.7, equation 2 results in levels in relatively good agreement with the observed ones, when it is considered that fallout data on strontium-90 are less complete than the available data for cesium-137 and that, in some circumstances, both data have been derived from assessments based on precipitation measurements when fallout data have been lacking.

Strontium-90 in milk from dairies with a small milk production in the mountain regions has been measured since 1963. Using equation 3 with p_d = 0.3 and p_r = 0.8 and on the assumption that the annual deposition is proportional to the annual precipitation, the calculated strontium levels in milk are 64 ± 23 percent (extreme limits) of the observed levels.

Correlations between cesium-137 levels in meat and milk

Monthly averages for the whole country of cesium-137 concentrations in beef and pork have been calculated from data reported by Åberg[3] (*65–66*).

Meat samples are taken from eight regions A-H (figure 7). The nationwide average is calculated as an arithmetic mean of samples from these regions with corrections for missing values.

[3] B. Åberg, personal communication.

The circles in figure 7 show the location of the sampling dairies of which four large dairies, marked with filled circles, have been used since 1965 for the calculation of the weighted nationwide average cesium-137 concentration in milk.

It was found by Lindell and Magi (*13*) that up to 1965, a satisfactorily good correlation between cesium-137 in meat and milk was obtained by the following relationship.

$$c_{beef}(j) = g_m \cdot M(j-1) \quad \ldots (4)$$

$$c_{pork}(j) = g_p \cdot \frac{1}{12} \sum_{k=j-1}^{k=j-12} M(k) \quad \ldots (5)$$

where

$c(j)$ = the calculated cesium-137 concentration in meat for month j.

$M(j-1)$ = the concentration of cesium-137 in milk in the preceding month $j-1$.

g_m = 4.34 ± 0.17 pCi/kg per pCi/liter

g_p = 4.64 ± 0.17 pCi/kg per pCi/liter

The measurements during 1966 showed that the relationship was still valid for beef (*25*) but not pork, for which the following relationship was derived based on data from August 1962 to March 1966.

$$c_{pork}(j) = A\overline{M} + BM(j) + CM(j-1) \quad \ldots (6)$$

where

$\overline{M}$ = the average cesium-137 concentration in milk during the grazing season, June–October of the preceding year, with a changed value for October, taken as the average between the two grazing seasons.

A = 1.8 pCi/kg per pCi/liter

B = 1.0 pCi/kg per pCi/liter

C = 0.5 pCi/kg per pCi/liter

From the 1967 measurements, the relationship for beef (equation 4) is found to be valid up to 1969 with the exception of the third quarters of 1967 and 1968, when the calculated beef activity is about three times the observed values (figure 14).

A comparison between milk and beef radioactivity from the same regions showed that the relationships were acceptable for those regions where the dairies are representative. Hence, the less satis-

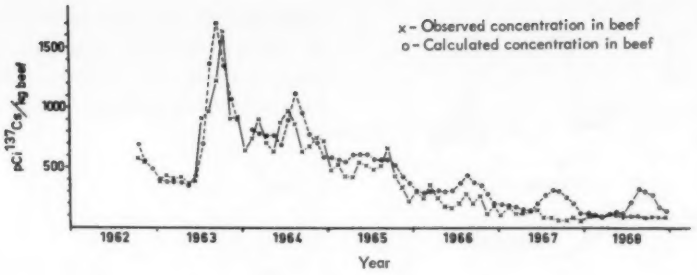

Figure 14. Nationwide averages of the observed cesium-137 concentrations in beef and calculated beef concentrations according to equation 4

factory agreement for the past years between the observed and calculated cesium-137 concentration in beef for the whole country may depend on the actual differences in the methods of calculating the nation-wide averages for beef and milk.

The measurements in pork for 1967 and 1968 were found to give a poorer correlation than earlier measurements when calculated by equation 6. From figure 15 it is seen that the calculated nationwide averages for the cesium-137 content in pork are about twice the observed values during 1967 and 1968.

Since the correlation between pork and milk radioactivities is obviously not as direct as that between beef and milk activities, comparison of the calculated and observed cesium-137 concentrations in pork for each region is likely to give more ambiguous results than a similar comparison for beef. However, an investigation of the five regions where sampling dairies are situated showed that the averages calculated for 5 years were between the extreme limits of 75 and 165 percent of the observed values.

Cesium-137 in reindeer meat

Since the autumn of 1961, samples of reindeer meat have been collected twice a year and measured at the Institute. As a rule, samples have been requested from 13 regions (A–M) shown in figure 16, although it has only been possible to obtain samples from both winter and autumn slaughters from only one of these regions during the whole period. Nowadays, since the reindeer slaughters usually take place in the autumn, these past few years it has been difficult to cover identical regions during both autumn and winter. Since the winter slaughter of 1966/1967, the sampling program has been decreased to four regions A, E, F, and I.

The values obtained since the sampling program was decreased to four regions have been found to agree to within ± 10 percent with values obtained from the earlier, more comprehensive program, when samples from at least three of the four regions were received and a correction for the selection of regions was made. The variations of the mean (corrected for the actual selection of

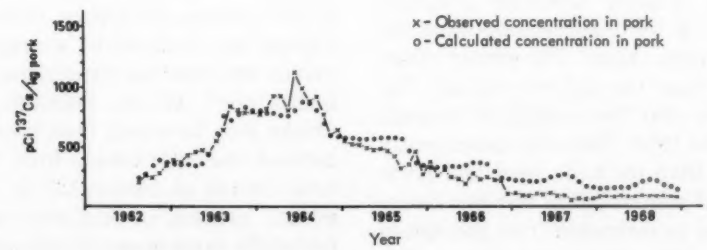

Figure 15. Nationwide averages of the observed cesium-137 concentrations in pork and pork concentrations calculated according to equation 6

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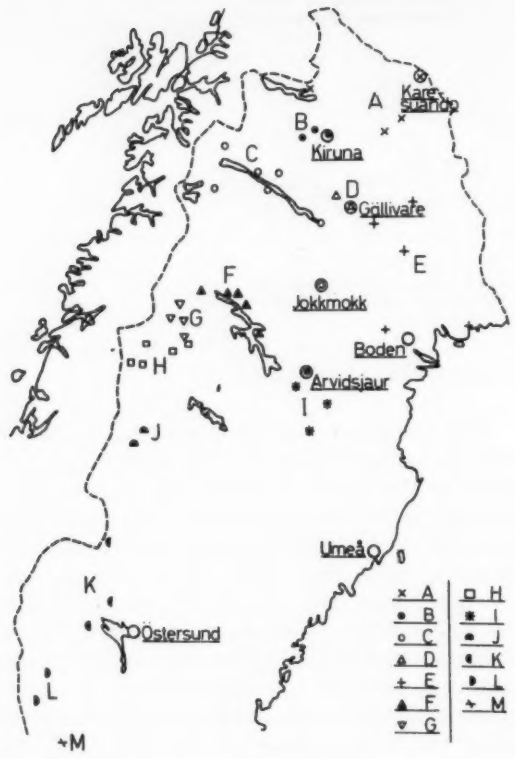

Figure 16. Regions in Sweden sampled for reindeer meat

regions each time) are shown in figure 17, where the highest and the lowest values are also indicated. The lowest values from 1966/1967 and later have been excluded because neither of the regions with the lowest cesium contents (H and J) are included in the reduced sampling program. The errors indicated for 1967 and 1968, refer to the experimentally determined deviations resulting from the reduced sampling program. A constant feature is the difference between the winter and the autumn values. The winter values have been higher than the autumn values. The diagram also shows that the maximum occurred during the winter of 1964/1965 and consequently considerably later than for milk, beef and pork.

The "half-life" of cesium-137 in reindeer seems to be about 4 years, as estimated from the values for samples from the winter slaughters. The values from autumn slaughters have increased since 1966. It is not possible to exclude the possibility that this is a result of the reduced sampling program, despite the correction for the selection of regions on each occasion. Hence, it has not been possible to estimate the "half-life" for values from the autumn slaughters.

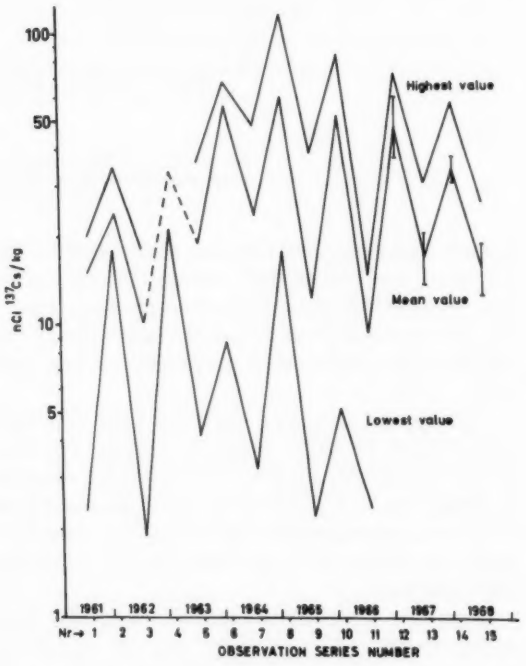

Figure 17. Cesium-137 content in deep-frozen reindeer meat
(Errors indicated are the maximum errors given by reduction in sampling program)

Cesium-137 in the diet

The total intake of cesium-137 in the diet can be estimated from the measured cesium-137 content in the most common foodstuffs and their proportion in a normal diet. Table 2 is a summary of the cesium content in various foodstuffs calculated as nationwide averages. Some of the values are based on measurements made by other institutes[3,4,5] (*65–66*). Potatoes, fruit, vegetables, drinks, etc., have only been measured sporadically because the contribution from these items to the total intake of cesium-137 is small due to low cesium content or low consumption. Imported foodstuffs cause some uncertainties in the estimation of the averages.

[4] L. Hannerz, personal communication.
[5] A. Eriksson, personal communication.

Table 2. Summary of cesium-137 content in foodstuffs during 1962-1968

Date	Nationwide averages (pCi/kg)						
	Milk	Beef[a]	Pork[a]	Grain[b]	Fish from salt waters[c]	Fish from oligotrophic lakes[c]	Reindeer meat
1962	120	380	190	305	100	2,000	17,000
1963	185	750	580	765	100	2,000	17,000
1964	180	760	845	310	100	5,000	39,000
1965	125	470	445	125	100	5,000	20,000
1966	70	230	235	65	100	5,000	14,000
1967	50	105	85	40	100	4,500	20,000
1968	40	95	85	40	100	4,000	17,000

[a] Data from the Royal Veterinary College.
[b] Data from the Royal Agricultural College.
[c] Data from a department of the National Nature Conservancy Office.

A summary of the annual cesium-137 intake as nationwide averages is given in table 3 for 1962–1968. These values were calculated on the basis of the values in table 2 and a normal composition of the diet (*67*). No direct measurements on diet samples have been made. The information regarding the composition of the diet is valid for 1960 and possible changes of dietary habits have not been considered. The foodstuffs not included in the table were estimated to make up about 10 percent of the total intake of cesium-137 excluding the contribution from reindeer meat. This estimation is based on both sporadic Swedish measurements and on measurements on Danish foodstuffs (*68–71*). The latter show that root vegetables, fruit, eggs, coffee, and tea amount to 6–19 percent, with a mean of about 10 percent of the annual cesium-137 intake during 1962–1967. We can expect that the percentage part denoted "others" varies with time, but because it contains several components, some of them imported, the variation of the individual foodstuffs compensate each other to a large extent.

Because some foodstuffs (for example, milk) to a large extent are consumed in the regions where produced, variations of the cesium-137 intake are found for different parts of the country. For example, in the Stockholm area, the cesium intake is about 60 percent of the intake estimated as the nationwide average.

The cesium content of various foodstuffs differs both with regard to the absolute level and variation with time. Foodstuffs with high cesium-137 content do not usually belong to the normal diet. An exception is reindeer meat, which constitutes a considerable part of the diet of the Lapps. Of great importance are the common foodstuffs—milk, beef, pork, and grain. They have a lower cesium content but together have contributed more than 70 percent of the total cesium-137 intake during 1963–1965, the years with the highest total cesium-137 intakes.

Table 3. Summary of annual cesium-137 diet intake from various foodstuffs

Year	Nationwide averages (nCi/person)						
	Dairy products	Meat	Grain[b]	Lake fish from oligotrophic lakes	Salt water fish	Reindeer meat	Total intake including "others"[d]
Average annual consumption per person	Milk 175 kg[a] Cheese 18 kg[a]	48 kg[a]	88 kg[a]	Fish consumption 17.6 kg[c]		0.3 kg	
1962	[e] 23.0 (41)	18.2 (33)	n	2.5 (4)	1.6 (3)	5.1 (9)	56
1963	35.1 (37)	28.8 (30)	13.4 (14)	2.5 (3)	1.6 (2)	5.1 (5)	95
1964	33.8 (25)	38.4 (28)	33.7 (25)	6.3 (5)	1.6 (1)	11.7 (9)	137
1965	23.7 (30)	22.1 (28)	13.6 (17)	6.3 (8)	1.6 (2)	6.0 (7)	80
1966	13.4 (29)	11.0 (24)	5.6 (12)	6.3 (14)	1.6 (3)	4.2 (9)	46
1967	9.7 (30)	4.3 (13)	2.8 (9)	5.6 (17)	1.6 (5)	6.0 (18)	32
1968	7.4 (29)	4.3 (17)	1.8 (7)	3.8 (15)	1.6 (6)	5.1 (20)	26

[a] Data from the National Swedish Institute of Public Health.
[b] Estimated: 50 percent in flour and consumption of the harvest of the preceding year.
[c] Estimated: divided into lake fish 2.5 kg and salt water fish 15.1 kg. About half of the lake fish is estimated to be from oligotrophic lakes.
[d] Estimated: "others" is 10 percent of the total intake excluding reindeer meat.
[e] Within parenthesis: percentage of total intake of cesium-137.

As shown in table 3, the relative contribution of the various foodstuffs to the total intake varies with time. As the cesium-137 content of usual foodstuffs has decreased, the relative contribution from other foodstuffs has risen. The relative increase of the contribution from fish and reindeer meat depends on the fact that the cesium content in these foodstuffs does not decrease with the same time pattern as milk, beef, pork, and grain.

From 1964 to 1968, the total intake of cesium-137 has decreased by about 80 percent.

Cesium-137 body burden

Measurements of the cesium-137 activity in human beings have been made four or five times a year on a group of about 20 persons employed at the Institute. The age of the members of the group is between 20 and 60 years. The calculation of the average was corrected for the differences occurring in the composition of the group. As seen from figure 18, the cesium-137 activities were calculated per gram potassium. In this way a quantity less dependent on body weight and sex is obtained. Its variation can thus be studied more easily and univocally. Table 4 illustrates the differences between cesium-137 levels in males and females. As is shown in table 4 and figure 18, the body burden reached a maximum in 1964 and has since decreased with a "half-life" of about 2 years. From measurements in Denmark and the United States of America, the "half-life" is reported to be 1½ years (*71*, *72*). The difference in the "half-lives," as in absolute activity levels, reflects the variation in the cesium-137 content of the foodstuffs and in the composition of the diet in various countries. The effect of an occasional change of the composition of the diet is illustrated by the October 1967 value in figure 18. A large number of the members of the group ate reindeer meat twice during September and October with a significant increase in the cesium body burden as a consequence.

Table 4. Cesium-137 in humans[a]

Date	Number of persons			Cesium-137[b] (nCi/person)		
	Total	Female	Male	Mean	Female	Male
May 1966	23	10	13	19.2	11.5	25.0
October 1966	23	9	14	15.9	11.1	18.9
April 1967	22	9	13	13.3	6.9	17.7
June 1967	19	8	11	14.2	6.3	20.0
October 1967	21	8	13	17.1	7.7	22.8
February 1968	22	9	13	14.1	5.6	19.9
May 1968	17	6	11	12.2	3.9	16.7
September 1968	15	6	9	11.9	4.0	17.2
November 1968	16	5	11	10.1	3.5	13.1

[a] Measurements made on a group of about 20 persons employed at the Institute.
[b] Corrected only for radon-222.

Because the measured group consisted of only 20 persons, not randomly chosen, it cannot be considered as representative for Stockholm and still less representative for the whole country. Using the estimated cesium-137 content in the diet given in the preceding section, body burdens can be estimated and compared with the observed ones. The result is shown in figure 19. The calculations were based on the cesium-137 content in the Stockholm diet and an effective half-life of 100 days. Despite a rather rough method of calculation (constant intakes per year)

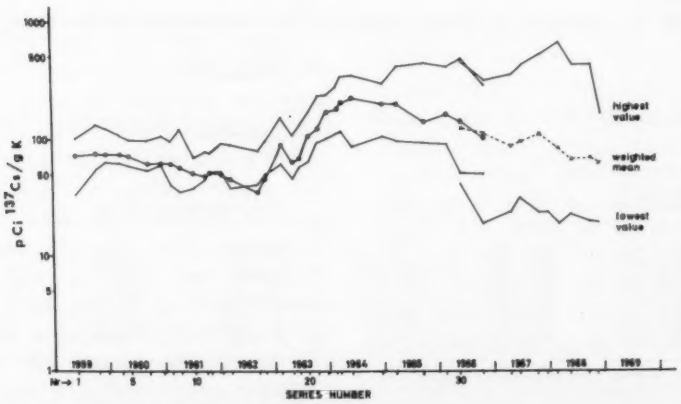

Figure 18. Cesium-137 body burdens of a group of Stockholm residents

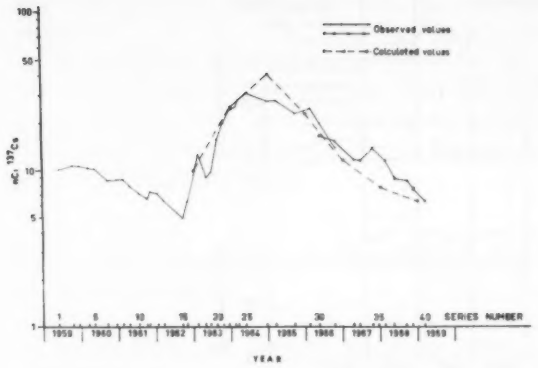

Figure 19. Observed body burdens compared with calculated body burdens

and the uncertainty in the representativeness of the group for Stockholm, a comparatively good agreement between the calculated and the observed body burden was obtained.

Gamma radiation at ground level

Measurements of the gamma radiation at ground level have been performed continuously since 1960 (*7*, *12*, *19*, *24*, *33*) at 24 places in Sweden, distributed over the country as indicated on the map in figure 20. Since the beginning of 1967, only the records from the five stations named on the map have been used for evaluating the exposure. Records from the other stations were examined only as a check.

The variation in the exposure in μR/h during the period 1960–1968 is shown in figure 21 for one station (Erken) located in central Sweden and one (Torslanda) in southern Sweden. The broken lines indicate the level found during the summer months of 1960 and 1961 before the large nuclear weapon tests of 1961 and 1962. The dot-dashed lines indicate the contribution from cosmic radiation. To illustrate the absorption in the snow cover, the monthly averages of the snow cover have been indicated at the bottom of each diagram. The values regarding the snow cover are based on data issued by the Swedish Meteorological and Hydrological Institute.

From figure 21 it is seen that the depth of the snow cover has a striking influence on the gamma-radiation level. Other variations due to natural factors depend on the freezing of the ground,

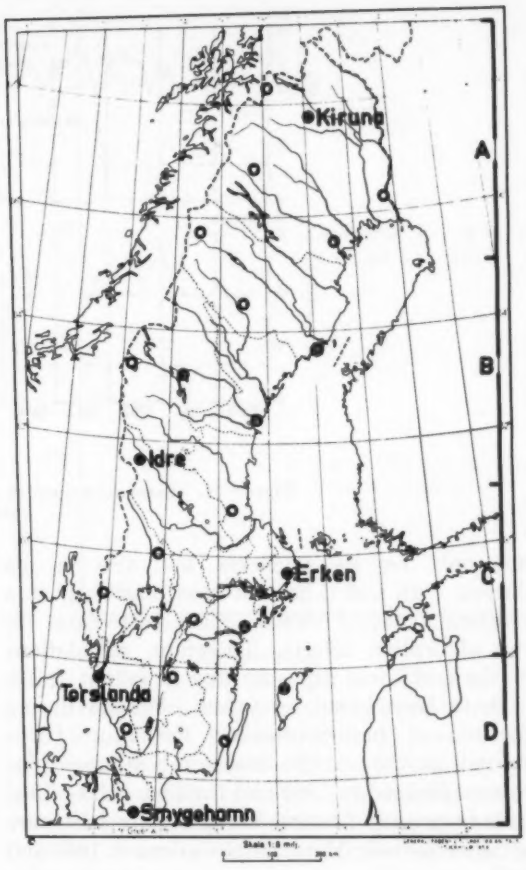

Figure 20. Stations for recording gamma radiation from the ground

variations in air pressure, precipitation etc. Precipitation can give rise to short increases up to 20 percent (*55*). Variations due to air pressure are of the same magnitude but of longer duration. The natural gamma radiation at ground level, based on values from the summer seasons, varies for the various stations between 62 and 96 mR/a of which about 30 mR/a is the contribution from cosmic radiation. The differences in these background levels depend on differences in the radioactivity in the ground under the ion chamber. Particularly in the north of the country, there is a seasonal variation of the exposure above the ground, depending to a large extent on the absorption in the snow. During 1960–1961, measurements of the natural radiation were made and corresponding variations were found. The absorption of radiation by the snow cover depends

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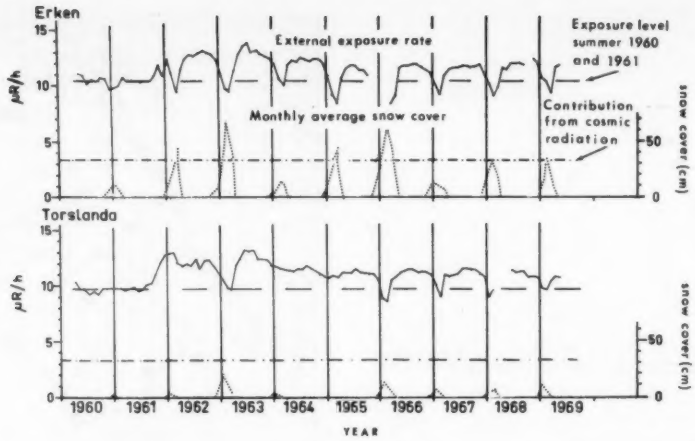

Figure 21. External exposure rates and monthly averages of the snow cover

not only on its thickness but also on its density (*73*), and it has not been possible from a practical point of view to make corrections for the absorption effects. Therefore, calculations of the additional exposure due to fallout (table 5) have been based on values obtained during the summer (June–September). For natural background at the various measuring stations, the values obtained in 1960 and the first half of 1961 have been used. Natural background values were obtained for only 11 of the 24 stations in 1960 and 1961.

As a comparison to annual values calculated from data obtained during the summer months, the exposures due to fallout based on annual values have been calculated and are given in brackets in table 5. These values are influenced not only by variations in the exposure due to fallout but also by variations in the snow cover from year to year, mostly for the stations in central Sweden. This is shown particularly for station C3. In 1960–1961, this station had exceptionally little snow. Therefore, the background value used will be overestimated during snow-rich years, such as 1965 and 1966, and the net exposure per year will be too low.

The maximum deviations between the additional exposure calculated on values from four stations compared with values from 11 stations were found to be 0 to +2 mR/a. The four sta-

Table 5. Annual exposures due to fallout from gamma radiation at ground level[a]

Station	Latitude	Background radiation[b] (mR/a)	Additional exposure due to fallout (mR/a)							
			1961	1962	1963	1964	1965	1966	1967	1968
B6 Idre	62°	78		11	25	16	13	10	11	12
		(70)	(3)	(10)	(19)	(17)	(12)	(7)	(7)	(8)
C3 Erken	60°	91		22	26	16	10	13	11	13
		(91)	(1)	(16)	(15)	(13)	(2)	(1)	(7)	(8)
D2 Torslanda	58°	85		21	29	16	14	14	12	14
		(85)	(6)	(21)	(19)	(15)	(11)	(9)	(10)	(8)
D6 Smygehamn	55°	62		11	17	9	7	6	6	7
		(63)	(1)	(12)	(13)	(7)	(6)	(4)	(4)	(5)
Average of 4 stations				16	24	14	11	11	10	11
			(3)	(15)	(17)	(13)	(8)	(5)	(7)	(7)
Average of 11 stations[c]				17	24	14	12	13		
			(5)	(16)	(19)	(13)	(9)	(6)		

[a] Calculated on the basis of values obtained during the period June–September. Values in parenthesis represent average exposures based on values obtained during the whole year (including absorption in the snow).
[b] Total before 1961, including the contribution from cosmic radiation.
[c] See text.

tions used for calculations since the beginning of 1967 can therefore, be considered as fairly representative.

The maximum additional exposure due to fallout occurred during 1963 and has been followed by a decrease with an approximative half-life of 2 years. During the past 4 years, the values have been fairly unchanged.

Fractionation phenomena from leakage from underground nuclear test

On the 25th and 26th of December 1966, a temporary increase of fallout was observed. The event has been reported earlier (*31*) and similar observations were made at other measuring stations in Sweden (*74*) and in Finland (*75*). The absolute activities in Sweden appeared to have no significance from the dose point of view, but the composition of the radioactivity was interesting.

About 9 p.m. (central-European time) on December 25, 1966, a significant increase in air radioactivity was measured by the continuously running air monitor. It decreased to normal values about 25 hours later. According to the results from the air monitor, the air radioactivity was 50 pCi-h/m³, i.e. the average concentration was 2 pCi/m³ with a maximum of about 2.5 pCi/m³. The part of the air filter corresponding to the time in question was measured by gamma spectrometric methods and the spectrum showed marked peaks which, by their energy and half-life were identified as barium-lanthanum-140. No other radioactivity could be found.

Radioactivity in precipitation from the period December 24 to 27, 1966, was measured by gamma spectrometic methods and two close-lying peaks were found at energies corresponding to cesium-137 and zirconium-niobium-95, and another at the energy, 480 keV (beryllium-7). There was no indication of any peaks corresponding to barium-lanthanum-140 (figure 22). There was no precipitation on the 26th of December, when, according to the air monitor, the radioactivity concentration in the air was at a maximum. The activity which fell as dry deposition the same day was evidently not enough to be measurable in the precipitation sample.

Several measurements were made on the precipitation samples at later times. Determination

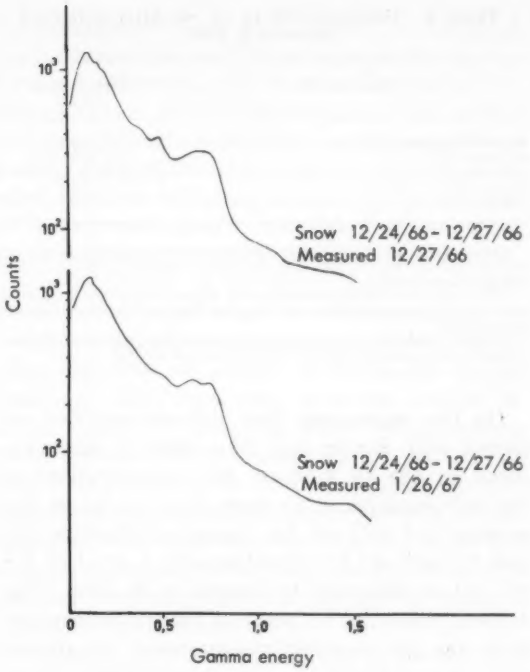

Figure 22. Radioactivity in precipitation

of the half-life resulted in $T_{1/2}$ = 81 days for the peak around 750 keV (the measurements were made for about 2.5 months). The energy and the half-life indicated zirconium-niobium-95 with an effective age of some months. The other peak (within 600–700 keV) showed no significant decay during the same measuring period. The energy and the long half-life indicated the presence of cesium-137.

The section of the air filter corresponding to the time of interest was radiochemically analyzed for strontium. The analysis and the beta measurement were made according to the method used for foodstuff (page 488). The content of strontium-90 and strontium-89 was determined; the first was identified by precipitation of yttrium-90; the latter, by determination of the half-life.

The results of the measurements are seen in table 6. The activity was calculated to the 2d of January 1967 (see below for comparison with the Japanese measurements). The amount of barium-lanthanum-140 was estimated from the gamma spectrometric measurements. The percentage contribution of the different components to the total activity is seen in table 7.

XUM

Table 6. Radioactivity in an air filter collected January 2, 1967

Radionuclide	Measurement (pCi)
Barium-lanthanum-140	[a] 380
Strontium-89	370 ± 20 (1σ)
Strontium-90	2.30 ± 0.3 (1σ)
Cesium-137	[b] 10
Others	[c] 100

[a] The activity values of barium-lanthanum-140 cannot be given with greater accuracy than ± 30 percent because of the lack of direct calibration for these nuclides.
[b] The maximum activity of cesium-137 was estimated from the gamma spectrometric measurement on the air filter after barium-lanthanum-140 had decayed.
[c] "Others" indicates the maximum gamma activity which can be estimated from gamma spectrometric measurements on air filter.

On the assumption that the radioactivity occurred only during that time when it was measured by the air monitor, the concentrations of the radionuclides in air were found to be on the average 1.6 pCi/m³ for barium-lanthanum-140, and 1.2 pCi/m³ for strontium-89; a total of 2.8 pCi/m³ as calculated to December 26, 1966. This value is somewhat higher than the one determined from the air monitor measurement (maximum value was 2.5 pCi/m³ with the calibration date given.) The difference in the results can probably be explained by the fact that the efficiency of measurement is overestimated. The efficiency of filtration, (said to be 70 percent) has no influence on this comparison, as it is included in both values. After a plausible correction of the values, the comparison shows that there is no room for any "other" beta radioactivity of importance, which agrees with the results in table 7.

Table 7. The percentage contribution to the total radioactivity

Radionuclide	Percentage
Barium-lanthanum-140	44
Strontium-89	43
Strontium-90	[a] .1
Cesium-137	1.2
Others	12

[a] The strontium-90 value for a filter which represents the time before the time of interest is subtracted from the strontium-90 value.

The above mentioned observations are worthy of attention not because of the quantitative results which are quite negligible from the point of view of radiation protection, but because of the radioactive elements which were found in the fallout and the relationship between them. The last above-ground nuclear test which could influence the measurements of fallout on the 25th–27th of December 1966 was the Chinese nuclear test of October 27, 1966. However, the time difference (60 days) makes it improbable to find such pronounced barium-lanthanum-140 peaks in the spectrum of an air sample without any other significant peaks. On the contrary, there are reasons to believe that the air radioactivity comes from a leakage from an underground nuclear test explosion. On January 30, 1965, Koyama et al. (*76*) measured fallout in Japan, which they could prove to have been caused by a leak from a Russian underground nuclear test explosion on the 15th of January the same year. They found the radionuclide composition in precipitation that is presented in table 8. Their values are compared with the composition that would be expected 15 days after fission of uranium-235.

Table 8. Percentage contribution to the total radioactivity, Japan, January 30, 1965

Radionuclides	Measured	Expected
Strontium-89	60	4
Strontium-90	.6	.03
Barium-lanthanum-140	34	26
Cesium-137	.2	.03
Others	5	70

The elements and their relative amounts which are measurable after a leakage are determined partly on the basis of the properties of their radioactive precursors. This means that during the leakage, there is an enrichment of those elements whose precursor is a gas (krypton, xenon) with an appropriately long half-life. For this reason, strontium-89, barium-140, and lanthanum-140 appear in the relatively high portions shown in table 8. Iodine-131, which normally dominates fresh fallout after nuclear test explosions above ground, was not reported in the Japanese observations. On the other hand, tellurium-iodine-132 could be found. This is due partly to the fact that during a given time there is a greater production of tellurium-132 by decay of the short-lived 132-isobars in the decay chain, Sn-Sb-Te-I than the production of tellurium-131 from the decay of 131-isobars.

Other factors will also influence the immediate fractionation and the fractionation which is observed at a long distance from the leakage (for

instance, meteorological conditions). It is thus difficult to predict the composition of the activity with any great accuracy or to be able to draw any conclusions concerning the source of the activity from the observed composition of the fallout activity. If one compares the fallout observed on the air filter on the 25th–27th of December 1966 with the fallout from the leakage observed abroad, there is obviously a similarity in the fractionation, indicating that the fallout observed in December 1966 was caused by a leakage from an underground nuclear test. Such a test was made on December 18, 1966, in the Semipalatinsk area in central Asia. At that time, the meteorological conditions were such that it is plausible that the observed increase of the fallout level in Sweden could have been caused by leakage from that underground test.

The radioactivity, observed in precipitation during the period December 24–27, 1966 (no precipitation on the 26th of December), did not have the same composition of gamma-ray emitters, as the air radioactivity. The presence of zirconium-niobium-95 and the absence of barium-lanthanum-140 is fairly characteristic of fallout caused by a nuclear test above ground (the latest before the time of measurement was the test on October 27, 1966) and does not indicate fallout from a leakage.

Discussion

Extensive fallout measurements were begun before the large nuclear weapon tests in 1961 and 1962 and have continued since then for a period of nearly 10 years. It has been possible to follow the radioactive contamination of the environment in all its phases, from the large and rapid increase during 1962–1963, its maximum during 1963–1964, and its slow decrease to levels, which today in some parts of the environment, are hardly measurable. As mentioned in the introduction, the purpose of the measurements was to obtain a nationwide picture of the magnitude and the variation of the radioactive contamination in different parts of the country and during different periods of time. The purpose was also to find the relationships between the radioactivity in different parts of the environment and in the human being, in order to gain a practical basis for action in possible future increases in fallout activity. Because of the purpose and the plan of the measurements, it was outside the scope of the investigations to examine in detail the reasons for local differences and time differences of the contamination of the environment. The correlations presented are empirical and the magnitude and variation of the contamination of the environment has been explained against the background of known ecological, meteorological, or other factors, or they have been presented just as facts. Therefore, many of the data which have been presented will call for further investigation.

Our investigations concern predominantly cesium-137. The occurrence of iodine-131 during 1961 and 1962 has been presented earlier by Lindell (*13*). In the period after 1963, there has been no measurable contamination by iodine-131. The strontium-90 content in milk has also been routinely examined. Other nuclides in fallout, such as zirconium-niobium-95, have not appeared in measurements on foodstuffs but have had an influence on the amount of external radiation from the ground.

The radioactive contamination of the environment depends primarily on the available activity on the ground and in the air. As found by measurements on air and precipitation[2] (*58–61*) the fallout rate of cesium-137 and strontium-90 reached its maximum in 1963 and the accumulated fallout reached its equilibrium value in 1966–1967. The time variation of the activity in different diets and in the human body reflects the influence of those factors which determine the further transport of the radioactivity in the environment such as ecological and biological factors, storage, etc.

The most direct connection between the radioactivity (per unit of area and time or accumulated) and the contamination of the environment should be found in the direct measurements of radiation above the ground. However, interpretation of these measurements, as some function of the fallout activity, will be complicated by seasonal screening effects, the penetration of radioactivity into the ground and radiation from airborne activity. The results are unambiguous as a measure of the exposure above the ground. The gamma radiation is primarily due to cesium-137, with the exception of the time immediately after a nuclear test when short-lived radioactive nuclides contribute to the exposure. The maximum during 1963 corresponds to a maximum in the airborne

XUM

radioactivity and the fallout rate. The subsequent slow decrease of the exposure rate ceased in 1965 and since then has been fairly constant. In contrast to this, the airborne radioactivity and the fallout rate have continuously decreased except during the past 2 years, when new contributions of fresh fallout have occurred.

As discussed in the gamma radiation at ground level section, there are difficulties from a practical point of view in making corrections for the absorption of gamma radiation in the snow. The best values of the yearly exposure of all stations in central and northern Sweden are obtained if the averages based on values from the summer season (table 5) are multiplied by 0.8, provided the accumulated activity does not change considerably during the year and the winter is not unusually snow rich. For the stations in southern Sweden, the corresponding factor is close to one. Without any detailed knowledge of the snow conditions or specification of the measuring place, the uncertainty will thus be about 25 percent.

The variation of the cesium-137 content in milk has largely followed the same time pattern as the variation of the fallout rate with significant peaks during the spring and summer months, indicating that it is mainly the fresh fallout which will be found in milk. The connection is complicated by the fact that cows do not graze outdoors until spring. This fact alone would indicate an increase in the radioactivity in milk, even under conditions of equal deposition rate during the year. It has also been possible to show a connection between the yearly fallout and the cesium-137 content of milk with good agreement between the calculated and the observed levels of cesium-137, up to 1966. Thereafter, the observed values have been higher than the calculated levels. The cesium-137 content of milk has been fairly constant since 1966, perhaps due to the relatively greater importance of the accumulated fallout. In this case, the influence of different soils, fertilizer, etc., in different agricultural areas should be more noticeable.

As seen in figure 8, the cesium-137 content in milk from different dairies has also changed differently in comparison with the calculated nationwide average. This is also seen in figure 9, showing an increasing difference with time between the cesium-137 content in milk from Tarnaby and that from Malmö, representing two different agricultural regions.

The radiation exposure to man caused by the radioactive fallout consists partly of external exposure primarily from radioactivity on the ground, and partly of internal exposure from the accumulated radioactivity in the body. Large local variations may occur as far as the internal exposure is concerned because of different diets. For instance, the Lapps in the north of Sweden have a higher cesium-137 body burden than the nationwide average because of their higher consumption of reindeer meat. However, Gustafsson and Liden (*16*) found that the increase of the total exposure caused by the consumption of reindeer meat does not fall beyond the limits of variations in natural radiation exposure to other persons. Those whose consumption of milk and meat is low, constitute a group with low cesium-137 body burdens. As seen from table 3, the difference in the percentage of cesium-137 intake via different foods was smaller during the past years. Earlier, fish and reindeer meat contributed to the nationwide average by less than 10 percent of the total intake of cesium-137. In 1967 and 1968, these foods together contributed almost 40 percent of the cesium-137 body burden since the rate of decrease of cesium-137 in these foods is lower than in other foods. This implies that the difference between extreme values of the body burden should increase with time, which is also seen in figure 18. In this case, the maximum values represent a man whose consumption of reindeer meat was higher than the other persons of the study group.

In the calculation of the absorbed dose, only the nationwide average was considered. The radiation doses were calculated with regard to cesium-137, and table 9 shows the doses to the gonads in mrads/a, where the values in table

Table 9. Absorbed doses to the gonads from cesium-137 deposition in the body

Year	Dose (mrad/a)
1962	2.4
1963	4.3
1964	6.8
1965	5.4
1966	3.3
1967	2.1
1968	1.6

3 for the yearly intake of cesium-137 were used. The corresponding mrad value was calculated by using the factor 9.5 mrad/a per nCi/kg (*77*). The absorbed dose rate from the body burden of cesium-137 had its maximum at 6.5 mrad/a in 1964 and the total dose during the period 1960–1970 will be 31 mrad, if the radioactivity continues to decrease according to the pattern of the past few years. As a comparison, the maximum dose rate to the Lapps was, on the average, about 100 mrad/a in 1965.

The external irradiation can be estimated from the measured radiation exposures presented in table 5. However, large uncertainties are involved in such an estimation because of the wide variations in screening of radiation by house walls, washout of activity from asphalted streets, etc. With a correction factor of 0.2 (*64*) for the screening, etc., the external doses are obtained according to table 10.

Table 10. Absorbed dose from external exposure due to fallout

Year	Absorbed dose (mrad/a)
1962	2.6
1963	3.8
1964	2.2
1965	1.8
1966	1.8
1967	1.6
1968	1.8

UNSCEAR (*63*) gives a factor of 0.008 mrad/a per mCi $^{137}Cs/km^2$ for the calculation of the dose to the gonads caused by gamma radiation from fallout on the ground. According to measurements in Sweden (*60, 61*) the amount of cesium-137 deposited since 1966 is 55 mCi/km^2 and the calculated dose is 0.44 mrad/a. The factor 0.008 is the product of 0.2 and 0.04. The correction factor for screening, etc, is 0.2, and the factor in air is 0.04 mrad/a per mCi/km^2. This factor was accepted by UNSCEAR in 1966 on the basis of the results from Beck (*78*) and Gustafson (*79*). Earlier the factor was assumed to be 0.12. Lindell (*80*) showed by theoretical calculations that if the activity was deposited on an infinite plane the factor is 0.06 mrad/a per mCi/km^2 at 1 meter above ground, disregarding the absorption in the ground and buildup in the air. Hence, the factor 0.12 includes a buildup factor ≥ 2 and an absorption factor ≤ 1. With this factor, the calculated dose is 1.3 mrad/a, which is in better agreement with the measured values. However, the agreement could be a coincidence. The accumulated fallout on the ground since 1966 is said to be 55 mCi/km^2 as an average for Sweden. There are, of course, local variations and the accumulated radioactivity on the ground close to the measuring stations is not known.

The total natural radiation to the gonads is about 100 mrads/a in Sweden, with variations between 50–300 mrads/a (*81*). Thus the external radiation caused by fallout was, at the most, 4 percent (1963) of the natural radiation to the gonads. The additional internal irradiation due to cesium-137 was, at the most, 7 percent (1964). The total irradiation to the gonads due to cesium-137 in the body and the external irradiation from the ground during 1960 to 1970, will be about 5 percent of the natural irradiation.

Because of the low radiation doses caused by fallout activity, even to those who had experienced the highest exposures, no remedial action has been considered justified. Any reasonable action to reduce the exposure, such as, changing the dietary habits, also involves certain risks which are likely to be more serious than the effect of the radiation dose. As already mentioned, there were also large variations in natural irradiation and, as a rule, the additional radiation doses caused by fallout have fallen within the extreme limits of the values from natural radiation.

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XUM

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XUM

Environmental Survey of Uranium Mill Tailings Pile, Monument Valley, Ariz.

Robert N. Snelling[1]

At the request of the Navajo Tribal Council through the Public Health Service Division of Indian Health at Window R ck, Ariz., an environmental radiological survey was conducted on the Foote Mineral Company's uranium tailings pile, Monument Valley, Ariz., in May 1968. The purpose of the survey was to identify any radiation hazards which might exist and recommend methods for their control. The survey included evaluation of external gamma radiation, airborne radioactivity, and waterborne radioactivity.

The results of the survey indicate that existing radiation levels do not exceed recommended exposure limits. However, to minimize the possibility of increased activity from weather conditions different from those existing during the survey, it was recommended that the mill tailings be stabilized against wind erosion. Otherwise, periodic monitoring will be necessary in the future.

In April 1968, the Division of Indian Health requested the Bureau of Radiological Health to conduct a study of the Foote Mineral Company's (FMC) tailings pile located at Monument Valley, Ariz., to identify any radiation hazards which might exist and recommend methods for their control. In response to this request, the tailings area was surveyed in May 1968.

The mill site is located on the Navajo Indian reservation approximately 17 miles from Mexican Hat, Utah. The property is leased to the milling company by the Navajo Tribal Council. The surrounding land is arid and sparsely populated, although there are several private dwellings within one-half mile of the tailings area. The land is utilized primarily for cattle and sheep grazing with some limited farming. The mill was designed and operated for the upgrading of low grade uranium ore and is at present inactive. The mill property is divided into two areas: the tailings and stockpile area, and the housing area.

The original tailings pile was reprocessed for recovery of uranium and disposed in a new location. The old tailings area, the ore stockpile area and the present tailings pile are shown in figure 1. The present tailings pile covers approximately 25 acres and contain an estimated 1.5×10^6 tons of tailings material.[2] The radium content estimated from the average uranium assay of mill feed material (assuming radium in equilibrium with uranium) is approximately 90 pCi/g or a total of 122 curies.[2]

There are several dwellings located in the vicinity of the old mill and tailings area. One dwelling was occupied by the mill superintendent during the period of the survey.

Sampling procedures

External radiation measurements were obtained using a portable Geiger survey meter. Gamma (closed window) readings were obtained at the surface and at the 3-foot level. A grid was established over the area and readings obtained at 250-foot intervals. A total of 82 pairs of readings was recorded.

In addition to the portable instrument readings, three thermoluminescent dosimeters (TLD) were placed at the 3-foot level at each of the air sampling stations and inside the mill superintendent's house (figure 1). The TLD's respond only to gamma radiation.

Wind direction and speed were estimated by visual observation. The predominant wind direction at the mill site for the 10-day sampling period was from the south. According to FMC personnel, this is the predominant wind direction throughout the year. During the first 6 days of

[1] Mr. Snelling is with the Technical Services Program, Southwestern Radiological Health Laboratory, Bureau of Radiological Health, Las Vegas, Nev.

[2] Division of Raw Materials, USAEC, 1967.

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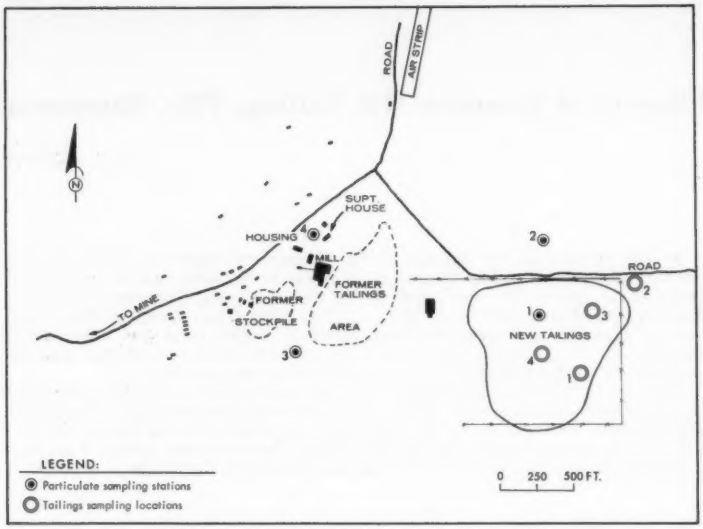

Figure 1. Air and tailings sampling locations, Monument Valley uranium mill

sampling the wind was light (0–5 mph). During the last 4 days, however, winds estimated at 10–20 mph were encountered. In general, lapse conditions were encountered during daylight hours with slight inversions at night.

Long-lived airborne particulate radioactivity was sampled by drawing air through a 0.8-micron pore size filter. A high-volume air sampler was used at a flow rate of about 5 cubic feet per minute. Four sampling stations were established on and about the tailings area (figure 1). Continuous 24-hour samples were obtained at stations 1, 2, and 3 on each of 10 consecutive days. Since electric power was available only between the hours of 4:30 p.m. and 8:30 a.m. at station 4, the air at this station was sampled only during this 16-hour period. Each individual filter was analyzed for gross long-lived alpha radioactivity. In addition, all filters from each station were composited for analysis of radium-226, thorium-230, and natural uranium.

Atmospheric samples for radon gas were obtained by grab sampling with a 2-liter flask. The stopcocks of the flask were opened and air was pulled through the flask for 5 minutes at a rate of 10 liters per minute after first passing through a 0.8-micron pore size membrane filter. At the end of the sampling interval, the flask was allowed to come to atmospheric pressure and the stopcocks were closed. The samples were picked up by the Public Health Service aircraft and flown to Las Vegas, Nev., for immediate analysis of radon-222. Samples were collected at six locations on one or more occasions for a total of 11 samples (figure 2).

Ground water samples were obtained from five wells in the area. One-gallon grab samples were obtained and analyzed for radium-226 and natural uranium activity.

Samples of tailings material were collected at the locations indicated in figure 1. Approximately 400 cc of surface material were taken from each location. The samples were analyzed for thorium-230, radium-226, and natural uranium.

Analytical procedures

All laboratory analyses were performed at the Southwestern Radiological Health Laboratory. Gross alpha and gross beta radioactivity determinations were performed after sample preparation by counting directly in an end-window, gas flow proportional counter. Radon-222 analysis was performed by cryogenic separation and subsequent alpha-particle scintillation counting. Radium-226 was determined after sample preparation by the radon emanation technique; uranium analysis was accomplished by the fluorometric technique; and thorium-230 analysis was performed by means of solvent extraction and subsequent alpha-particle counting.

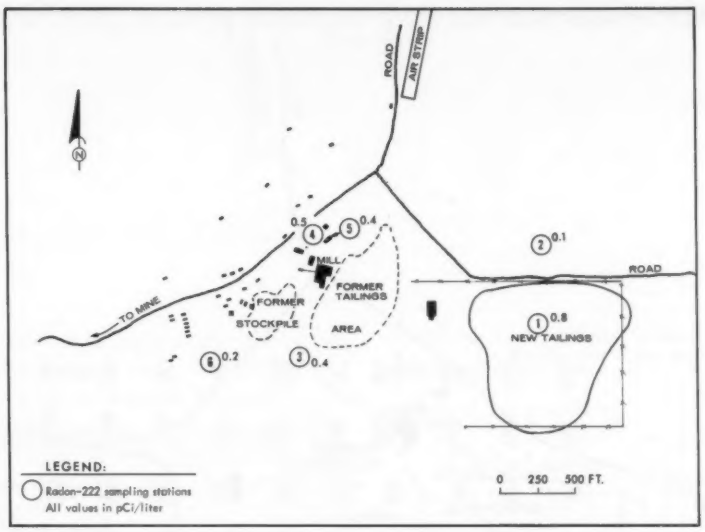

Figure 2. Atmospheric radon-222 sampling stations, Monument Valley uranium mill

Table 1. External radiation measurements, Monument Valley uranium mill, May 1968

Area	Number of measurements	Radiation at surface (mR/h)		Radiation at 3 feet (mR/h)	
		Average	Range	Average	Range
Background	6	0.04	0.03–0.06	0.04	0.02–0.06
Housing area	8	.04	.02– .07	.04	.01– .05
Tailings and stockpile area	50	.09	.02– .3	.08	.03– .2
Perimeter	18	.03	.02– .04	.03	.01– .04

Results

Table 1 summarizes the gamma radioactivity measurements obtained at the surface and at 3 feet for the various areas. Figure 3 indicates the location and magnitude of individual measurements. The background radiation level in the surrounding areas was found to average 0.04 mR/h both at the surface and at 3 feet. The radiation exposure at the 3-foot level in the tailings and stockpile area was found to range from a minimum of 0.03 mR/h to a maximum of 0.2 mR/h with an average of 0.08 mR/h. There was no significant difference between the readings at 3 feet and those at the surface. The radiation exposure at 3 feet in the housing area was found to average 0.04 mR/h. This exposure represents normal background levels of radiation. Measurements made along the perimeter of the property (approximately 200 feet from the fence) averaged 0.03 mR/h. This represents background levels of exposure. A comparison of the results obtained from the TLD's and the portable instrument measurements is shown in table 2. The results are in good agreement.

Table 2. Comparison of TLD and Geiger meter data, Monument Valley uranium mill, May 1968

Station number	Radiation measured by (mR/h)	
	TLD	Geiger meter
1	0.07	0.07
2	.02	.02
3	.05	.06
4	.09	.07
Inside superintendent's house	.05	.12

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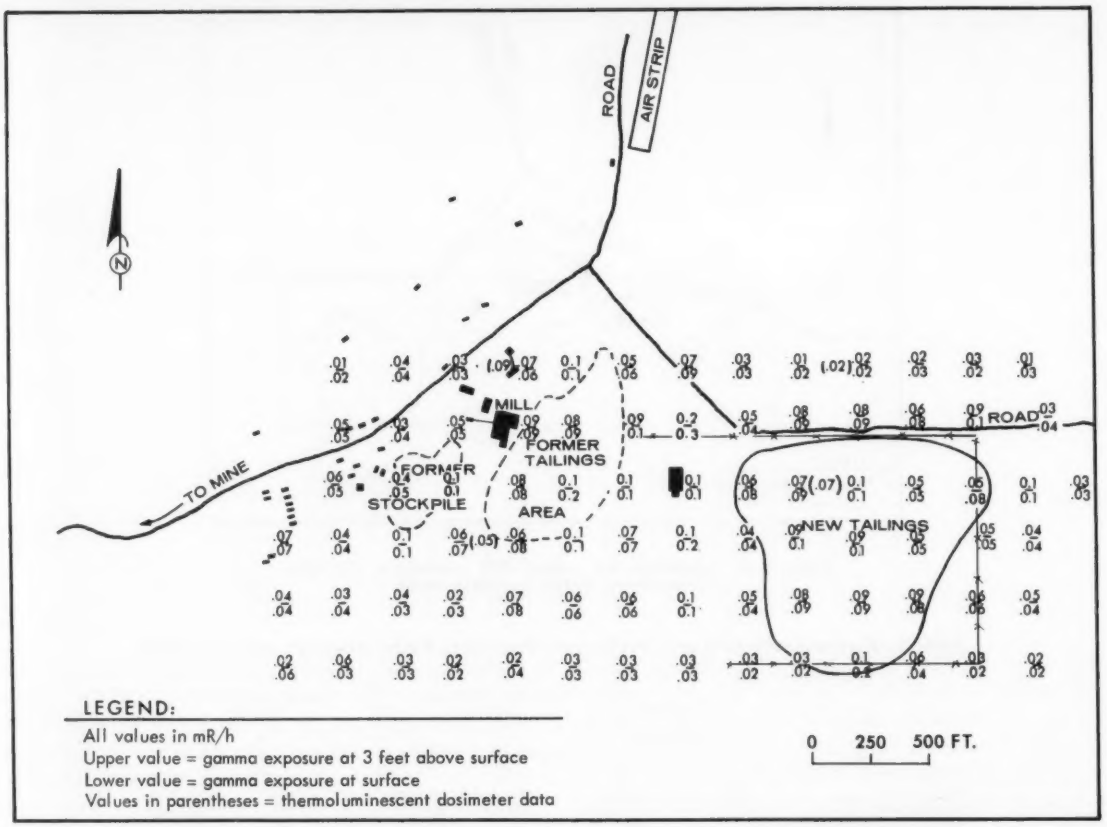

Figure 3. External radiation measurements, Monument Valley uranium mill

Table 3. Gross long-lived alpha radioactivity of particulates in air, Monument Valley uranium mill, May–June 1968

Station number	Gross alpha radioactivity (fCi/m³)											
	May 1968			June 1968							Six day average[a]	Total average[a]
	29	30	31	1	2	3	4	5	6	7		
1	21	[b] <10	<10	12	(c)	52	424	(c)	(c)	(c)	18	103
2	<10	22	79	<10	<10	<10	395	55	(c)	(c)	14	70
3	36	<10	<10	71	<10	<10	(c)	(c)	(c)	(c)	16	16
4[d]	10	79	33	<10	<10	21	499	35	338	40	23	103

[a] Average is weighted in accordance with sample volume collected.
[b] Assumed equal to zero for averaging.
[c] Sampler failure.
[d] Samples collected between 1630 and 0830 m.s.t.

The long-lived gross alpha radioactivity on particulates found on individual filters is shown in table 3. The upwind station (No. 3) averaged 16 fCi/m³ gross alpha radioactivity over the first 6 days. No valid samples were obtained from station No. 3 during the last 4 days because of recurrent sampler failure. The downwind stations showed no significant difference from station No. 3 during the first 6 days. During the last 4 days, when strong winds were encountered, a significant increase in alpha radioactivity was noted for all three downwind stations. The average gross alpha

Table 4. Average long-lived radioactivity in air, Monument Valley uranium mill, May 1968

Station number	Gross alpha (fCi/m³)	Radium-226 (fCi/m³)	Thorium-230 (fCi/m³)	Natural uranium (ng/m³)
1	103	23	45	62
2	70	5	7	12
3	16	1	6	14
4[a]	103	6	11	40

[a] Sample collected between 1630 and 0830 m.s.t.

radioactivity for the total collection period for downwind stations ranged from 70 fCi/m³ at station 2 to 103 fCi/m³ at stations 1 and 4.

Table 4 shows the average gross alpha radioactivity along with radium-226, thorium-230, and natural uranium activity for each station for the entire sampling period.

Table 5 summarizes the radon-222 activity concentrations found at specified sampling times and locations. Figure 2 shows the average radon concentrations at each sampling location.

Table 5. Atmospheric radon-222, Monument Valley uranium mill, May 1968

Station number	Radon-222 (pCi/liter)			
	5/28, 1445 m.s.t.	6/3, 1000 m.s.t.	6/6, 1000 m.s.t.	Average
1	0.5	0.4	1.5	0.8
2	.1			.1
3	.3	.4		.4
4		.5		.5
5				
(inside house)	.7	.4	.2	.4
6 (background)	.2			.2

Table 6 summarizes the average radium-226 and natural uranium results for the five water sampling stations. Stations 3 and 5 can be considered as background stations because of their distance from the tailings area. There is no significant difference between the samples taken in the vicinity of the pile and background samples.

Table 6. Radioactivity in ground water, Monument Valley uranium mill, May 1968

Station number	Location	Number of samples	Radium-226 (pCi/liter)	Natural uranium (μg/liter)
1	Superintendent's house, well	1	0.1	18
2	Luke Yazze's well, ¼ mile south	1	.2	6
3	Tom Adaci's well, ½ mile east	1	.1	4
4	Tony Yazze's well, ½ mile east	1	1.5	ND
5	Cain Valley Spring, well 4 miles north	1	.5	2

Table 7 summarizes the results of the thorium-230, radium-226, and natural uranium analyses on tailings material. The radium content on the tailings samples averaged 59 pCi/g. This average is somewhat below that predicted from the average assay of mill-feed material (90 pCi/g). The thorium-230 averaged 46 pCi/g and natural uranium averaged 33 μg/g (0.003 percent). A soil sample taken 100 feet northeast of the pile displayed results of the same order of magnitude.

Discussion

The code of Federal Regulations, Title 10, Part 20, indicates a maximum allowable whole body dose to an individual in an unrestricted area of 0.5 rem in any period of 1 calendar year. The regulations further indicate a maximum allowable dose for continuous exposure to individuals in an un-

Table 7. Tailings sampling, Monument Valley uranium mill, May 1968

Area	Number of samples	Uranium (μg/g)		Thorium-230 (pCi/g)		Radium-226 (pCi/g)	
		Mean	Range	Mean	Range	Mean	Range
Tailings pile	3	33	17–49	46	28–56	59	48–77
100 feet NE of pile	1	18	—	27	—	31	—

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restricted area of 2 millirems in any 1 hour or 100 millirems in 7 consecutive days.

The Radiation Protection Guide (RPG) adopted by the Federal Radiation Council recommends that the yearly radiation exposure to the whole body of individuals in the population (exclusive of natural background and the deliberate exposure of patients by practitioners of the healing arts) should not exceed 0.5 rem (*1*). The council further recommends, however, that every reasonable effort should be made to keep exposures as far below this level as possible.

To evaluate the potential long-range hazard associated with the external radiation emitted from the tailings material, the average yearly whole body exposure for an individual having 24-hour per day residence on the area was calculated and compared to the recommended RPG of 0.5 rem/a. The net gamma radiation (i.e., minus background) at 3 feet was used for this computation.

The average exposure at the 3 foot level on the tailings and stockpile area was found to be 0.08 mR/h. The whole body average yearly dose for an individual having 24-hour per day residence on the tailings would be approximately 0.35 rem/a (calculated from the average net exposure of 0.4 mR/h). This dose is less than the RPG of 0.5 rem/a. The highest single measured exposure of 0.2 mR/h (0.16 mR/h net) at 3 feet would result in a yearly dose of 1.1 rem for continuous exposure. This is two times the RPG of 0.5 rem/a but represents the unlikely condition of continuous occupancy. With reasonable occupancy assumptions, it would not be expected that a yearly average dose in excess of 0.5 rem would occur. The housing area showed background levels of exposure.

In order to assess the potential long-range health hazard associated with the inhalation of airborne radionuclides, the average radioactivity concentrations on airborne particulates observed for each sampling station were compared to the recommended radiation concentration guides as indicated in The Code of Federal Regulations, Title 10, Part 20. Because the guides are applicable to yearly average concentrations, this comparison assumed that the meteorological conditions imposed during the sampling period were representative of the yearly average conditions.

The Code of Federal Regulations, Title 10, Part 20, indicates a radiation guide for unidentified natural radionuclides in air of 80 fCi/m³ (when protactinium-231 is assumed absent). If gross alpha radioactivity is above this guide, identification of the specific radionuclides contributing to the total alpha radioactivity is necessary in order to evaluate the potential long-range hazard associated with the inhalation of the airborne particles.

The nuclides in the natural uranium decay chain most significant as potential health hazards are the alpha-particle emitters. These nuclides and their appropriate guides are:

Thorium-230 (soluble)	80 fCi/m³
Radium-226 (insoluble)	2 pCi/m³
Natural uranium (insoluble)	2 pCi/m³
Lead-210 (soluble)	4 pCi/m³
Polonium-210 (insoluble)	7 pCi/m³

It is apparent from comparison of these values with table 4 that none of the stations exceeded the guides for individual radionuclides for the sampling period. As expected, the station showing the highest concentrations was station 1 located directly on the tailings pile. At this station, radium-226 and natural uranium averaged factors of 100 and 30, respectively below their appropriate guide. Because of the low concentration of these nuclides in the tailings material it is not expected that these nuclides will exceed their guides downwind from the pile in the future.

Thorium-230 for station 1 averaged 45 fCi/m³. The other stations showed average thorium-230 concentrations ranging from 6 fCi/m³ at station 3 to 11 fCi/m³ at station 4. It is doubtful that concentrations downwind from the pile would exceed the guide of 80 fCi/m³ averaged over an extended period of time. However, it is impossible to predict this absolutely on the basis of less than 10 days of sampling.

The Code of Federal Regulations, Title 10, Part 20, indicates a radiation concentration guide for radon-222 in air in unrestricted areas of 3 pCi/liter above natural background. The daughters of radon-222 are assumed to be present to the extent that they exist in unfiltered air. (This is interpreted as meaning equilibrium conditions.) To evaluate the potential long-range hazard associated with the inhalation of radon and its progeny, the atmospheric radon concentrations were compared to this guide.

None of the radon samples collected on or about

the tailings area was above the recommended guide.

Ground water samples obtained in the vicinity of the tailings area showed background levels of radioactivity.

Summary

The net external gamma radiation on the tailings and stockpile area averaged 0.04 mR/h at 3 feet above the surface. This calculates to a yearly dose of 0.35 rem/a for continuous exposure and does not exceed the recommended Radiation Protection Guide (RPG) of 0.5 rem/a for continuous whole body exposure to individuals in the general population.

The housing area showed background levels of radiation.

The stations located downwind from the tailings area showed gross alpha concentrations on airborne particulates approximately equal to or in excess of the concentration guide (RCG) of 80 fCi/m^3 for unidentified alpha radioactivity. None of the stations exceeded the guides for radium-226, thorium-230, or natural uranium, however.

Radium-226 and natural uranium averaged a factor of 100 and 30, respectively, below their appropriate guide. Because of the low concentration of these nuclides in the tailings material, it is not expected that these nuclides will exceed their guides downwind from the pile in the future.

Thorium-230 concentrations averaged from one-tenth to one-half the concentration guide of 80 fCi/m^3 for the downwind stations. Although it is doubtful that concentrations downwind from the pile would exceed the concentration guide averaged over an extended period of time, this is impossible to predict on the basis of less than 10 days of sampling. On this basis it was recommended that the tailings pile be stabilized against wind erosion. This would preclude the possibility of exposure to thorium-230 in the future. If the pile is not stabilized, periodic sampling will be necessary to insure that concentrations of thorium-230 in air do not exceed the guide over an extended period.

Radon gas concentrations on and about the tailings area averaged approximately an order of magnitude below the guide of 3 pCi/liter.

Ground water samples obtained in the vicinity of the tailings area showed background levels of activity.

Recommendation

On the basis of the data gathered in this survey it was recommended that the mill tailings be properly stabilized against wind erosion. This action would preclude carriage of tailings material into the surrounding environment and would minimize any potential long-term hazard to anyone inhabiting the area downwind from the mill property. If the tailings area is not stabilized, periodic surveillance will be necessary to insure that significant wind carriage does not occur.

Followup

This study was conducted as part of the Uranium Mill Tailings Project being conducted at the Southwestern Radiological Health Laboratory. The objectives of the project are to gather information on the potential health hazards associated with uranium mill tailings and to institute control action where necessary.

The recommendations made following the survey of the uranium mill tailings pile at Monument Valley, Arizona, were forwarded to the Division of Indian Health and to the State of Arizona in preliminary form in November 1968. As of this writing, no action has been taken on the recommendations.

Acknowledgments

Sincere appreciation is expressed to the Foote Mineral Company for the cooperation and assistance provided during the survey. Without their cooperation, the study could not have been adequately performed.

REFERENCE

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XUM

Results of a Study of Color Television Set Assembly and Repair Workers X-Ray Safety

Stanley D. Savic[1]

A study was conducted to determine the degree of exposure of television set assemblers and repairmen to low levels of low energy x radiation. Two independent companies supplied the x-ray film badges on a biweekly basis. In addition, some television repairmen were also asked to wear thermoluminescent (TLD) ring badges so that the degree of hand exposure to x rays could be determined. In two large service shops, detailed records were also kept of the number and models of television receivers which were serviced. The largest total exposure recorded by film badges worn by any repairman during the one and a half year duration of the survey, was 34 mR. During that same time, no other badge showed any radiation, and therefore, we assume that this one film was inadvertently exposed to heat or some other element. In a later survey, there were a few scattered hand exposure readings ranging from 10 to 70 mR for TLD rings which were continuously worn over a 3-month period. These readings are also suspected to be false, because they were not repeatable with the same individuals and because hundreds of other TLD rings registered no dosage. During the 8 months duration of the factory assemblers' survey, over half a million color television receivers were produced by the 1,000 monitored employees. Not a single film badge worn in the factory assemblers' survey showed any radiation. We conclude that occupational x-radiation exposure of television repairmen and assemblers is virtually nonexistent.

At the Conference on Detection and Measurement of X-Radiation held in March of 1968, a paper (*1*) was presented which described preliminary results of a study into the x-radiation safety of television repairmen. That study has now been completed, and it is the purpose of this paper to give a full report of its findings. The results reported here will also summarize findings of an extensive color television factory assembly line personnel survey and monitoring program. This was done in the hope that it may cast some new light on the subject of x radiation from home television receivers, as well as provide helpful data to future researchers. These studies were initiated because we were unaware of any previously reported broad studies into TV repairmen's and TV factory assemblers' safety from possible exposure to low energy x radiation.

Background

The potential hazards of byproduct x-radiation emission from color television receivers to viewers have been the subject of numerous studies in the past. Guidelines were issued by the National Committee on Radiation Protection and Measurements (NCRP) in 1959 which arbitrarily established a recommended limit for x-ray emission from any normally operating home television receiver at 0.5 mR/h at any readily accessible point 5 cm from the surface (*2*). Although these guidelines have generally been observed by most manufacturers of television receivers, under certain conditions of high voltage regulation circuit maladjustments or failures which result in an abnormal increase in the high voltage, perhaps aggravated by high line voltages, some receivers were capable of exceeding the NCRP recommendation. The failures in high voltage regulation circuitry usually result in some other circuit or component failure which demonstrates itself to the viewer in one or more of several ways. These may take the form of a completely nonoperative receiver, periodic arcing accompanied by loud noise, or a repeated failure of some other component which thereby warrants much more frequent servicing (in home tube replacement, for instance). Most of these conditions ultimately necessitate

[1] Mr. Savic is Radiation Safety Officer, Zenith Radio Corporation, Chicago, Ill. 60639.

XUM

servicing of such a receiver in a service shop or a close examination of the receiver by the field serviceman in the user's home, and that is why we were interested in investigating the risk involved for television servicemen.

During the time of exposure, the user of such a receiver would be expected to be subjected to a lower exposure rate than that measured at close proximity to the set's surface. This is due to the rapid decrease of x-ray intensity with viewing distance. Intensity is reduced by a factor of approximately five for each meter in the direction away from the picture tube, and thus the total dose actually received at recommended viewing distances may be regarded as negligible. Without further study, the same could not have been said for the repairmen who must work in very close proximity to the components capable of emitting x radiation and also for factory assemblers who work in very close proximity to operating receivers or operating sections of the receiver chassis during certain factory tests. Finally, concern should also be given to the factory repairmen who work on sets rejected from the assembly lines because of faulty wiring which in some sets may result in elevated high voltage and possibly, in x radiation. These are the reasons we undertook our study.

Not every failure of a television set component will result in elevated high voltage or in additional x-ray exposure to the repairmen. In fact, the high voltage circuit of a television receiver is in many ways, one of the more reliable sections, and repairs generally amount to no more than the replacement of a vacuum tube. As wider use is made of solid state components in domestic TV receivers, time necessary for repair may increase also. However, it is anticipated that in the future, solid state devices, still in the developmental stage, may also be used for generation of picture tube operating voltages so that high voltage shunt regulator and high voltage rectifier vacuum tubes may be eliminated. These vacuum tubes were shown (*3–5*) to be major possible sources of x radiation in color television receivers.

At the time our surveys were conducted, Zenith Radio Corporation was no longer using high voltage shunt regulator tubes (6BK4) in television sets. Phasing out of these tubes began in 1966. The newer sets use a low voltage pulse regulator tube (6HS5) which does not emit x rays. This, however, does not detract from the validity of our repairman survey since a large percentage of the sets which were serviced in the three monitored repair shops had been produced prior to 1966. The exact percentage of receivers with shunt regulator tubes will be discussed below. The factory assembly workers, however, were not exposed to any sets with high voltage shunt regulator tubes. Their accumulated x-ray dose, if any, could only be due to rectifier and picture tube radiation, and therefore, their data must only be considered representative of the present conditions.

Film badge monitoring of assembly workers

For this survey, we employed the services of R. S. Landauer, Jr. & Company which provided us with clip-on x-ray film badges. These badges were issued to all employees who worked with, or in close proximity to, energized color television receivers or receiver chassis. Each film badge was worn for a period of 2 weeks in order to assure that even low levels of radiation accumulation could be detected. At the end of each working day, all badges were deposited in a previously designated place and reissued each morning. Male employees were instructed to wear the film badges clipped to either their shirt pockets or belts. Female employees were instructed to wear the badges clipped to their blouses or sweaters. This program was initiated on March 11, 1968, and lasted through November 17, 1968, at which time it was discontinued because not a single film badge showed any radiation at or above the minimum detectable exposure.

The total number of x-ray film badges worn by employees was 15,159. Since each film badge was worn for 10 working days, this amounted to a total of 151,590 film badge work days without any indication of radiation exposure in addition to that which is attributed to natural background radiation. The total number of color television receivers produced by all three Zenith plants which participated in the program was over half a million. This is summarized in table 1.

Table 1. Summary of information on film badge monitoring of color television receiver assembly workers

Duration of survey	March 11 to November 17, 1968
Number of work days (excluding holidays)	161
Average number of employees participating	940
Total number of film badges worn	15,159
Number of work days each badge was worn	10
Total number of film badge work days	151,590
Maximum exposure reported on any badge	0

Thermoluminescent dosimeters used in the factory

At the end of the factory film badge survey, 162 production line color television repairmen were asked to wear thermoluminescent (TLD) ring badges for two consecutive periods of 3 months each. This was done in order to determine if any hazards exist from hand exposure to malfunctioning sets. These badges were also supplied by R. S. Landauer, Jr. & Company. Individuals who were asked to wear the LiF ring badges were the same ones who had already participated in the earlier film badge survey. It should be noted that a factory repairman works on considerably more sets in any single day than does a field serviceman and that the total exposure equals the exposure rate multiplied by the time. Typically, a factory repairman works on 30 malfunctioning sets per day. The number of sets worked on by a field repairman would, because of travel time, generally be less than 10 per day. Factory failures encountered are very similar in nature to field failures. Table 2 gives the summary of results obtained during this survey which lasted from October 1, 1968, to March 31, 1969.

Table 2. Results of TLD ring badges worn by factory repairmen for 6 months

First 3 months		Second 3 months	
Number of badges	Reported badge exposures (mR)	Number of badges	Reported badge exposures (mR)
[a] 1	70		
[a] 3	20	1	20
[a] 8	10		
124	0	109	0
26	Destroyed or Missing	52	Destroyed or Missing
162 Total		162 Total	

[a] Each one of these badges showed no radiation in the second 3-month period.

From the results of the survey, one can see that, except for a single reported 3-month exposure of 70 mR, there were no readings higher than 20 mR, and none of the readings above background for the first quarter were repeatable during the second quarter. We attempted to arrive at an explanation for these readings but were unsuccessful. The wearers were allowed to take their ring badges home, and this may hold the explanation for destruction or loss of a substantial number of badges. We know that most employees found the ring badges a nusiance and were not too enthusiastic about wearing them. This may also explain the fact that the number of lost badges doubled during the second quarter. For that reason, we suggest that future researchers consider the use of a less cumbersome wrist TLD badge to monitor hand radiation.

Service shop survey

When it was first reported that a major color television manufacturer had become involved in an extensive recall program because of allegedly excessive amounts of x radiation which were emitted from certain models, we initiated a complete review of television receiver x-radiation safety. One of the first items was to visit several independent and several manufacturer-affiliated service shops. The list of questions of interest during those visits is shown in figure 1. In none of the shops did we come across a "problem", but we found that not all of the manufacturers' recommendations were always followed. This was particularly true with respect to measurements and adjustment of high voltage.

We next concentrated on three Zenith-affiliated large service shops. Two of the shops are located in Chicago, Ill., and the third one is in New York City, N.Y. Initially, we conducted an inspection of each of the three shops to determine those conditions which had to be considered for each shop and how many film badges would be required to adequately monitor x-radiation levels there. All film badges used in this survey were supplied by Nuclear Chicago Corporation which also read the badges and then sent the results to us. Previously, we had instructed Nuclear Chicago Corporation to interpret all their film density readings for the type of radiation which we anticipated; i.e., 25–35 keV x rays. The badge-wearing period was initially set at 1 week, but when the first few reports came in without any reported exposure, the wearing period was increased to 2 weeks. In addition to personnel badges which all color receiver repairmen were instructed to wear clipped to their shirt pockets, we also used in each shop five "area monitoring" film badges and one "control" badge. The "area monitoring" badges were positioned throughout the service shops on bench tops and other areas where one or more television sets could operate simultaneously while being repaired. The "control" badge was always kept sufficiently away

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FIELD INSPECTION REPORT

DATE:_____ COMPANY:_____

ADDRESS:_____

INSPECTION MADE BY:_____

WAS FIELD REPRESENTATIVE PRESENT?_____

1) HOW MANY PERMANENT SETUPS OR JIGS EXIST?_____

2) WHAT KIND? (DESCRIBE BRIEFLY)_____

_____

IF ANY X-RAY MEASUREMENTS ARE MADE ON THESE SETUPS, DESCRIBE THE RESULTS:_____

_____

3) HOW MANY SERVICEMEN ARE EMPLOYED WHO WORK ON COLOR TV?_____

4) DO THEY ADJUST HV ON EVERY SET?_____

5) IF NOT, WHEN DO THEY ADJUST IT?_____

6) DO THE FIELDMEN ADJUST HV WITH A METER?_____

7) ARE SERVICEMEN OR MANAGER AWARE OF POTENTIAL X-RAY HAZARDS?____

8) DO THEY REINSTALL SHIELDS?_____

9) DO THEY NOTICE HIGHER HV (ABOVE 27KV) ON SETS THAT COME IN?____

10) WHAT IS THE LINE VOLTAGE IN THE SHOP?_____

11) DO THEY ADJUST HV FOR 25KV OR IF AC LINE IN THE SHOP IS TOO HIGH OR TOO LOW, DO THEY COMPENSATE ACCORDING TO THE MANUAL?_____

12) DO THEY EVER "COOK" SETS AT ELEVATED HV OR LINE VOLTAGE?_____

Figure 1. Service shop survey form used to learn about servicing habits of color television repairmen

from any operating sets and was used to account for any possible false radiation reading which could be indicated by badges in transit.[2] As it turned out, two such shipments apparently did register false indications. In one shipment, all badges including the control badge showed between 30 and 42 mR. In the other shipment, the range was between 47 and 60 mR for all badges including the control badge.

The repairman survey was conducted continuously from July 10, 1967 to January 6, 1969. A total of 628 personnel film badges was worn by 18 color television repairmen for an accumulated 6,973 film badge work days. During the same period, a total of 586 "area monitor" film badge dosimeters was used. These area monitor film badges accumulated a total of 5,628 badge work days.

In order to better understand the significance of these film badge reports, detailed records were kept in the New York shop and in one of the Chicago shops. These records included chassis model numbers of each receiver worked on as well as the total number of each chassis type worked on. In the form (figure 2) used for this purpose the numbers in the column just to the left of the chassis model numbers refer to how many of each type of chassis were worked on in the shop. (The servicemen did not wear their film badges out of the service shops during home calls.)

From the information collected in the two shops we estimated that over 5,000 television receivers were repaired in the three shops by serviceman while they wore their film badges. Approximately 18 percent of these were of the shunt regulator type.

An "Excessive Film Badge Radiation Report Form" (figure 3) was used for this survey to enable a permanent record of the circumstances under which an individual may have received an overexposure. As it turned out, only one film badge showed a measurable radiation exposure, and that was 34 mR for 2 weeks. The only unusual fact about this badge was that it was worn during the month of August inside the pocket where humidity and temperature could conceivably combine to increase the fog level, but our conclusion that this was a false reading attributable to excessive heat and humidity can at best be accepted as only a guess (*6*).

Table 3 summarizes all of the data obtained for both the "personnel" and "area monitoring" film badges.

Table 3. Results of survey of three service shops in which television repairmen wore x-ray film badges for 1½ years[a]

Number of personnel badges	Exposure (mR)	Number of area monitor badges[b]	Exposure (mR)
1	34	2	1
627	0	584	0

[a] Number of "personnel" film badge days, 6,973. Number of "area monitor" badge days, 5,628. Number of receivers serviced (approximately), 5,000.
[b] Film badges were worn for 2-week periods.

Conclusions

Based on the results of these surveys, it is this writer's considered opinion that the potential for an accidental overexposure to low energy x radiation from home television receivers to television assemblers and repairmen is negligible and virtually nonexistent. Even if the highly suspicious unique readings are accepted as accurate, the maximum amount of radiation which could be attributed to occupational hand exposure observed for an individual would be 70 mR during a 6-month period, which is equivalent to 140 mR/a, and the maximum total body exposure of an individual during a period of 1 ½ years was 34 mR, which is equivalent to 22.5 mR/a. The arithmetic mean of the annual serviceman hand exposure due to television radiation as calculated from data presented in table 2 is equivalent to 1.9 mR/a. Similarly, from table 3, one can calculate the arithmetic mean for annual total body x-ray exposure of television servicemen to be less than 1 mR/a. It must be pointed out that there is almost no meaning in calculating the average x-ray exposures of servicemen since from these data one cannot construct an actual distribution curve; however, if calculation of such an average exposure were necessary, the answer would have to be zero radiation within the limits of measurement. The arithmetic means calculated from tables 2 and 3 are negligible when compared with recommendations issued by the International Commission on

[2] There are many reasons why a film badge might show exposure from causes other than radiation. These are heat, chemical fumes, etc., and they must be excluded if the reading is to be meaningful. On the other hand, if the badge shows no exposure, then one may assume that there has been no x-ray exposure.

December 12, 1968

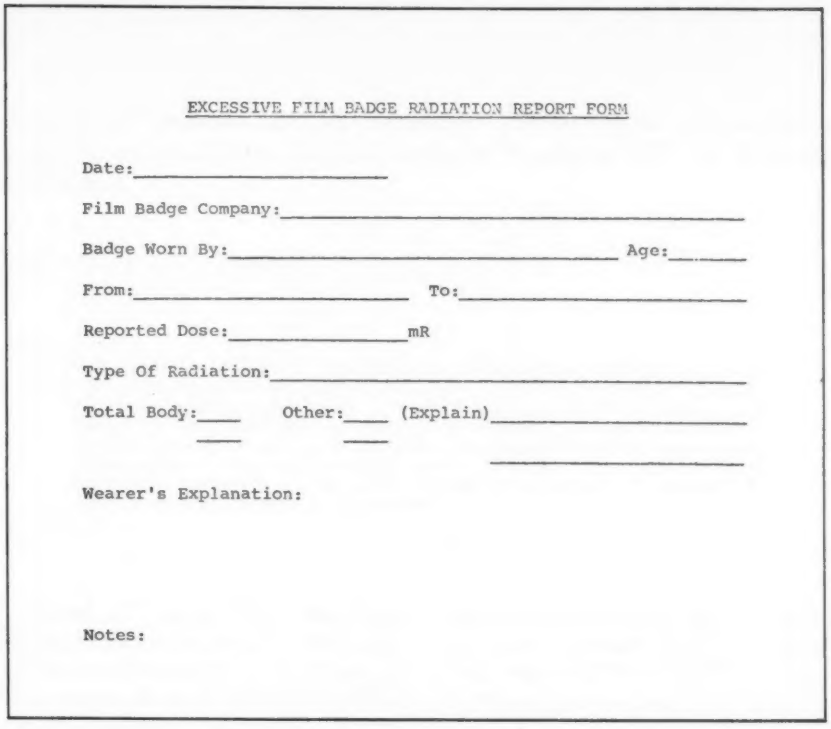
SERVICE LOCATION: 912 W. Washington

DATE SHOWN ON BADGES: 11/25/68

BADGE NUMBER	NAME	CHASSIS WORKED ON
	(Purposely Deleted)	
63313-08		6 16Z7C50
		2 20Y1C50
		1 20X1C38
63313-09		4 16Z7C50
		1 20X1C38
		5 20Y1C50
		2 25NC37
63313-10		15 16Z7C50
		11 20Y1C50
		2 20Z1C37
		1 15Y6C15
		1 25NC37
		4 23X1C38
63313-11		1 20X1C38
		5 20Y1C50
		6 16Z7C50
		4 15Y6C15
63313-12		10 16Z7C50
		2 20Y1C50
		3 24NC38
63313-13		6 15Y6C15
		11 16Z7C50
		5 20Y1C50
		2 20Y1C38
63313-26		1 20Y1C38

MANAGER
(Name Deleted)

Figure 2. Example of a completed form used to determine number and types of chassis serviced during survey



EXCESSIVE FILM BADGE RADIATION REPORT FORM

Date:_____

Film Badge Company:_____

Badge Worn By:_____ Age:_____

From:_____ To:_____

Reported Dose:_____mR

Type Of Radiation:_____

Total Body:____ Other:____ (Explain)_____

____ ____

_____

Wearer's Explanation:

Notes:

Figure 3. Reporting form used to document case history of each film badge that showed any x-ray exposure

Radiation Protection and the National Committee on Radiation Protection (*7*). Development of high voltage solid state devices, incorporation into rectifier and shunt regulator tube glasses of high x-ray absorbing materials such as lead, and replacement of barium in color picture tube panels by strontium, presently under way, will in our opinion even further reduce the already negligibly small exposure hazard.

Acknowledgment

The author wishes to acknowledge the help of Dr. John Post, Zenith's Medical Director, and Mr. Raymond Johnson, Northwestern University Radiation Safety Officer, for assistance in setting up and conducting these surveys. Thanks are also due to the managers of the service shops and their employees, without whose cooperation the job could not have been done, and to Miss Anna Marchetti for typing the manuscript.

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XUM

Elevated Levels of Cesium-137 in Common Mushrooms (*Agaricaceae*) with Possible Relationship to High Levels of Cesium-137 in Whitetail Deer, 1968-1969

Wallace Johnson[1] and *Chester L. Nayfield*[2]

High levels of cesium-137 exist in game animals of the southeastern United States. The highest levels, ranging from 250 to 152,940 picocuries per kilogram, have been found in muscle tissue of the Whitetail deer. Levels in Florida range from 10 to 100 times those encountered in Alabama. An important factor in the diet of these animals in Florida is the common gill mushroom, *Agaricaceae*. Examination of these fungi revealed cesium-137 levels higher by an order of magnitude than levels in vegetation. Similar concentrations of potassium-40 do not occur, indicating a selective effect.

Levels of cesium–137 range from less than 250 pCi/kg among wild animals found in the mountain regions of the southeastern United States to 152,940 pCi/kg among those of the lower coastal plains (*1*). Of all species investigated, Whitetail deer have the highest levels, particularly those from the Florida flatwoods. Levels among them are 10 to 100 times greater than deer of the same species from Alabama. Occurring in the winter months, November through January, the highest levels encountered were more than 300 times that of domestic livestock (*2*).

In Florida, in 1969, the mean level of cesium-137 in deer sampled was 19,615 pCi/kg wet weight with a range of 9,300 to 34,000 pCi/kg[3] (seven animals sampled). This agrees closely with unpublished data of Dr. James H. Jenkins and Timothy J. Fendley of the University of Georgia, relative to 60 samples of deer meat collected in Florida.

In contrast, in Florida, in 1967, the mean level of cesium-137 in grain-fed beef was 214 pCi/kg (statewide average of 33 animals sampled) with a range of 55 to 539 pCi/kg (*3*). Cattle, fed primarily on grass, averaged 4,000 pCi/kg with a range in lean meat of 290 to 12,500 pCi/kg (*4*).

The highest radionuclide concentration reported in meat is on the order of 10,000 pCi/kg. This level was calculated by Roessler et al. to result from an equilibrium concentration in grass of 10,000 pCi/kg dry weight, using a transfer coefficient (corresponds to fraction passing from gastrointestinal tract to blood) of 0.1 and assuming an intake of 10 kg of grass per day dry weight. In 1963–1964, Porter et al. reported the upper limit level of cesium-137 in pangola grass near Tampa to range from 3,700 to 9,600 pCi/kg dry weight (*5*).

Roessler et al. concluded that elevated levels of cesium–137 in domestic animal products appear to be due to the intake of elevated levels of the radionuclide with locally grown forages (*6*). Evidence suggests that an environmental mechanism is responsible for concentrating cesium-137 to an unusual degree in Florida since grain-fed animals do not show high levels. This type of feed is imported largely from other states. Since levels found in deer differ so markedly from domestic cattle on local forage, a food source of cesium-137 unlike local cattle forage would be expected.

On most Florida ranges, deer probably need between 5 and 80 pounds of feed per day, according to the Game and Fresh Water Fish Division, Florida Department of Natural Resources

[1] Mr. Johnson is Public Health Physicist, Radiological and Occupational Health Section, Division of Health of the Department of Health and Rehabilitative Services, State of Florida.

[2] Dr. Nayfield is Administrator, Radiological and Occupational Health Section, Division of Health of the Department of Health and Rehabilitative Services, State of Florida.

[3] Unpublished data, Radiological and Occupational Health Section, Florida Division of Health, 1969.

XUM

(7). Grass is not a significant part of their diet. It is eaten but in winter constitutes less than 1 percent of the diet. Contents of the stomachs of 423 deer, collected during the months of November to January (1953–1958), revealed that 85 percent of their diet consisted of oak acorns and leaves, palmetto berries, mushrooms, bamboo briar, deer's tongue, gallberry, titi, blueberry leaves, holly, Virginia willow, sweet bay, legumes, wicky, ferns, sumac, willow, elderberry, black haw, yellow jasmine, and blackberry leaves.

Food items found in deer rumen indicated that the diet consisted of 40.8 percent mast, principally acorns and palmetto berries; 37.6 percent woody plants; 11.4 percent herbaceous material; 9.2 percent mushrooms, and 1.0 percent grasses, pine needles, moss, Indian pipe, etc.

Materials and methods

Because of the elevated levels of cesium-137 in deer meat compared to domestic animals, it was decided to study the diet of deer to determine whether an item or items high enough in cesium-137 to support these body burdens could be demonstrated. An estimate of the levels of cesium-137 required in the deer diet was made utilizing the expression:

$$B = \sum_{i=1}^{i=n} fI \frac{t}{0.693} (1 - e^{-0.693(tm/t)}) (e^{-0.693(td/t)}) \quad (1)$$

Where

B = body burden of cesium–137 in pCi
f = fraction of cesium-137 passing from gastrointestinal tract to blood (taken as 1).
I = cesium–137 intake (pCi/day)
t = effective half-life of cesium–137 in days
tm = reporting period for intake values in days, and
td = period between ith period and period of body burden estimation.

This expression was adopted from reference (1) and with suitable modification it can be calculated that the concentration of cesium-137 in food required to maintain a body burden of 20,000 pCi/kg would be 2,300 pCi/kg net weight assuming the body burden to be 0 when t = 0, a body weight in an animal of 100 pounds (about 40 kg), and a daily food intake of 20 pounds (about 8 kg). This calculation assumes that the transfer coefficient is 1.0. If the value for transfer coefficient utilized by Roessler et al. is adopted (0.1) the value would be 23,000 pCi/kg wet weight which is in good agreement with the value for grass by that group.

During 1968, several forms of vegetation were sampled in preoperational surveillance of the Turkey Point reactor site in Dade County. We found a mean value in vegetation of 143 pCi/kg wet weight with a range of 45 to 671 pCi/kg wet weight. This range is similar to that of samples collected from other locations and appears too low, by about two orders of magnitude, to support the body burdens found in deer.

We collected a single sample of unclassified gill mushrooms (Agaricaceae) and analyzed it by gamma spectroscopy. The cesium–137 level was 11,000 pCi/kg wet weight. Analysis of samples collected in wooded areas or from lawns, logs, and trees at randomly selected sites in Duval, Clay and Dixie Counties also showed elevated levels of cesium–137 (table 1). These distributions of values are consistent with other reports (8).

The highest levels of cesium–137 are associated with wooded areas having a heavy layer of decaying humus and the lowest levels are associated with grassy, treeless locations, such as lawns. Levels in mushrooms collected in wooded areas appear high enough to support the body burdens found in deer.

The means of cesium–137 levels from mushrooms in different habitats are significantly different at the 95-percent confidence level utilizing the "Student-t" distribution. Means of potassium-40 levels are not significantly different at the 95-percent confidence level.

When cesium–137 levels of other foods in the deer diet were compared, we found the mean to be an order of magnitude lower than that of mushrooms collected from wooded areas. Results are shown in table 2 of analysis of Sabal palmetto leaves collected in preoperational sampling from a nuclear power plant site in Citrus County during May–September 1969.

Table 1. Concentration of cesium-137 and potassium-40 in unclassified mushroom species (*Agaricaceae*) and soil, Florida, August–October 1969

Sampling location	Sample	Fungus (pCi/kg wet weight)		Soil (pCi/kg wet weight)	
		Cesium-137	Potassium-40	Cesium-137	Potassium-40
Wooded areas (pine and oak)	1	11,000	[a]12,000		
	2	19,000	4,800		
	3	19,000	5,300		
	4	4,300	5,900	[a]1,400	490
	5	15,000	3,000	200	140
	6	15,000	2,500	200	140
	7	9,700	2,800	390	240
	8	8,900	3,100	160	170
	9	20,000	2,300	400	1,600
	10	29,000	3,700	400	1,600
	11	25,000	3,700		
	12	13,000	2,300		
Mean		15,700	3,580	292	626
Range		4,300–29,000	2,300–5,900	160–400	140–1,600
Lawns (principally St. Augustine grass)	1	230	3,800		
	2	220	3,800		
	3	250	4,900		
	4	200	4,600		
	5	140	990	520	ND
Mean		208	3,620		
Range		140–250	990–4,900		
Growing on logs, trees	1	1,100	6,400		
	2	1,200	5,600		
	3	1,300	2,500		
	4	2,000	650	500	ND
	5	4,600	1,100	400	1,600
Mean		2,040	3,250	450	
Range		1,100–4,600	650–6,400	400–500	

[a] Discarded as stranger.
ND, nondetectable, minimum detectable level—194 pCi/kg.

Table 2. Representative mean values for cesium-137 and potassium-40 levels in palmetto leaves—Crystal River, Citrus County, May–September 1969

Sampling location	Concentration (pCi/kg wet weight)			
	Palmetto leaves		Soil	
	Cesium-137	Potassium-40	Cesium-137	Potassium-40
01	148	6,100	130	ND
02	632	6,460	216	ND
03	348	2,740	466	ND
04	[a]3,040	3,660	402	ND
05	746	5,220	686	ND
06	[a]3,760	2,700	925	ND
08	130	5,640	50	ND
Mean	1,260	4,650	410	ND
Range	130–3,760	2,700–6,460	50–925	

[a] Pine wooded area.
ND, nondetectable, minimum detectable level-194 pCi/kg.

In table 3 are listed the means and ranges of cesium–137 in two grasses sampled during January to October 1969 in connection with preoperational surveillance around a nuclear power plant in Dade County.

Ranges of potassium–40 concentrations in foods from various locations are compared in table 4.

Discussion

Levels of cesium–137 as high as 150,000 pCi/kg of muscle have been found in Whitetail deer from certain areas of Florida. A level of 2,300 to 23,000 pCi/kg wet weight in foods would be necessary to support mean body burdens of

Table 3. Cesium-137 and potassium-40 levels in selected environmental vectors Turkey Point, Dade County, 1969

Vector		Concentration (pCi/kg wet weight)			
		Vegetation		Soil	
		Cesium-137	Potassium-40	Cesium-137	Potassium-40
Bermuda Grass (*Cynodon dactylon*)	Mean	190	4,357	401	ND
	Range	60–360	2,600–7,200	180–670	
Strawgrass (*Eleocharis*)	Mean	277	3,425	213	ND
	Range	130–460	2,000–4,300	70–310	

ND, nondetectable.

Table 4. A comparison of the ranges of potassium-40 concentrations from various Florida locations and vectors

Vector	Range of potassium-40 in vegetation (pCi/kg wet weight)	Range of potassium-40 in soil (pCi/kg wet weight)
Mushrooms from wooded areas	2,300–5,900	140–1,600
Mushrooms on logs, trees	630–6,400	
Mushrooms on lawns	990–4,900	
Palmetto (Citrus County)	2,700–6,460	520
Bermuda Grass (Dade County)	2,600–7,200	ND
Strawgrass (Dade County)	2,000–4,300	ND

ND, nondetectable.

20,000 pCi/kg if the ingestion period were confined to 6 months. We selected a 6-month ingestion period because mushrooms are not plentiful in north Florida during December to March. The fact that the highest levels of cesium-137 were found in deer during the early winter, and the lowest, in spring and early summer, would be consistent with seasonal appearance of mushrooms in north Florida. A lower intake during the winter months would result in lower body burdens in late winter and early spring.

The common gill mushroom is the only food sampled which had high enough cesium–137 levels to support the body burden found in deer. Ranges of reported levels of potassium–40 in all food and soil samples showed no significant variation. The value of the range of cesium–137 in mushrooms showed significant variation as related to habitat and between the highest levels and those encountered in other foods. It appears that high levels in mushrooms from wooded habitats constitute a true concentration of cesium–137 and not a variation in potassium levels. The concentration is consistent with the report that a common soil fungus (*Trichoderma viride*) concentrates cesium–137 by a factor of 10.4 over the levels in the substrate regardless of the donor substrate (*9*).

Conclusion

Levels of cesium–137 in deer of certain areas of Florida exceed levels found in domestic cattle by one or two orders of magnitude. A food containing high levels appears to be the source of this body burden. Analysis of the common gill mushroom (*Agaricaceae*) from heavily wooded areas revealed levels as high as 29,000 pCi/kg wet weight and a mean value of 15,741 pCi/kg. This elevation over levels in soil occurs without a similar concentration of potassium–40 and is thought to constitute a true selective concentration of cesium-137. Other reported deer foods have not been analyzed, and mushrooms may contribute only a portion of the cesium-137 body burden to deer. No vegetation samples have been analyzed by the Florida Radiological Surveillance Network which would support the reported high body burdens in deer at reasonable food intake levels. Mushrooms also appear to be a useful indicator for cesium-137 in the environment and may provide a basis for the high levels reported in deer. Other environmental samples, such as seeds, nuts, and palmetto berries, should be studied to provide clarification of the cesium transport to deer.

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XUM

XUM

SECTION I. MILK AND FOOD

Milk Surveillance, June 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation and Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in, or are formed as a result of, nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-

Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations (2σ), for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Serivce of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in the period, July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 14 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good which is encoruaging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analysis more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or

XUM

sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analysis (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discusses in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8, 9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data, one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0–200	200–2,000	2,000–20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c] 1.5	.5	[d] 200	0–20	20–200	200– 2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0–10	10–100	100– 1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0–360	360–3,600	3,600–36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.
[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the

Table 2. Protection Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c] 1,110,000
Strontium-90	Bone marrow			[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

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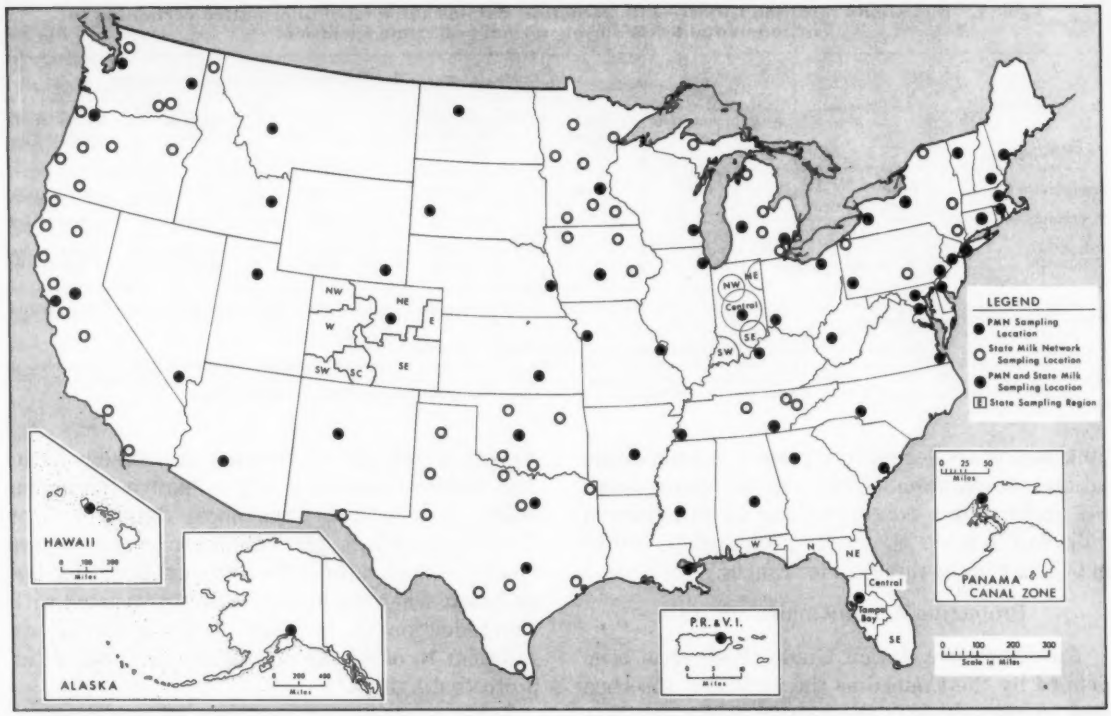

Figure 2. State and PMN milk sampling locations in the United States

appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* (The relationship between the PMN stations and State stations is shown in figure 2.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131, and cesium-137 for June 1970 and the 12-month period, July 1969 to June 1970. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great

Table 3. Concentration of radionuclides in milk for June 1970 and 12-month period, July 1969 through June 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	4	6	0 (4)	0	3 (4)	10
Alaska:	Palmer[c]	P	6	5	0 (5)	0	3 (5)	4
Ariz:	Phoenix[c]	P	0	1	0 (4)	0	0 (4)	0
Ark:	Little Rock[c]	P	16	14	0 (5)	0	18 (5)	18
Calif:	Sacramento[c]	P	4	1	0 (4)	0	0 (4)	0
	San Francisco[c]	P	4	2	0 (3)	0	0 (3)	0
	Del Norte	P	21	19	0	0	21	19
	Fresno	P	2	2	0	0	0	6
	Humboldt	P	5	5	0	0	11	6
	Los Angeles	P	2	2	0	0	0	3
	Mendocino	P	3	3	0	0	0	3
	Sacramento	P	3	3	0	0	0	3
	San Diego	P	3	8	0	0	0	2
	Santa Clara	P	3	2	0	0	0	2
	Shasta	P	3	3	0	0	0	3
	Sonoma	P	4	3	0	0	0	3
Colo:	Denver[c]	P	7	5	0 (4)	0	4 (4)	2
	West	R	(d)		NS	(e)	NS	4
	Northeast	R	(d)		(e)	(e)	(e)	(e)
	East	R	(d)		NS	(e)	NS	(e)
	Southeast	R	(d)		(e)	(e)	(e)	(e)
	South Central	R	(d)		NS	(e)	NS	NS
	Southwest	R	(d)		(e)	(e)	31	7
	Northwest	R	(d)		NS	(e)	NS	(e)
Conn:	Hartford[c]	P	9	8	0 (4)	0	18 (4)	11
	Central	P	9	7	0 (4)	0	20 (4)	12
Del:	Wilmington[c]	P	11	8	0 (4)	0	15 (4)	5
D.C:	Washington[c]	P	8	7	0 (4)	0	10 (4)	6
Fla:	Tampa[c]	P	3	5	0 (4)	0	57 (4)	53
	West	R	14	11	0	0	36	24
	North	R	13	11	0	0	32	25
	Northeast	R	5	7	0	0	30	44
	Central	R	5	7	0	0	98	46
	Tampa Bay area	R	5	7	0	0	54	48
	Southeast	R	6	8	0	0	83	73
Ga:	Atlanta[c]	P	12	10	0 (4)	0	18 (4)	18
Hawaii:	Honolulu[c]	P	3	2	0 (5)	0	0 (5)	0
Idaho:	Idaho Falls[c]	P	4	5	0 (4)	0	9 (4)	3
Ill:	Chicago[c]	P	9	8	0 (5)	0	14 (5)	8
Ind:	Indianapolis[c]	P	9	8	0 (5)	0	8 (5)	5
	Northeast	P	13	10	0	1	10	14
	Southeast	P	17	11	0	0	0	11
	Central	P	14	10	0	0	10	9
	Southwest	P	19	11	0	0	10	12
	Northwest	P	16	11	0	0	10	16
Iowa:	Des Moines[c]	P	6	6	0 (4)	0	3 (4)	2
	Iowa City	P	9	8	0	0	22	10
	Des Moines	P	9(4)	7	0 (5)	0	14	5
	Spencer	P	5	5	NA	0	NA	5
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[c]	P	8	8	0 (5)	0	3 (5)	0
Ky:	Louisville[c]	P	14	9	0 (5)	0	11 (5)	4
La:	New Orleans[c]	P	16	15	0 (4)	0	23 (4)	18
Maine:	Portland[c]	P	11	11	0 (4)	0	28 (4)	22
Md:	Baltimore[c]	P	10	8	0 (5)	0	10 (5)	7
Mass:	Boston[c]	P	13	11	0 (5)	0	28 (5)	21
Mich:	Detroit[c]	P	7	8	0 (5)	0	11 (5)	8
	Grand Rapids	P	11	9	0 (5)	0	15 (5)	11
	Bay City	P	NS	7	NS	(e)	NS	9
	Charlevoix	P	14	12	(e) (4)	(e)	20 (4)	18
	Detroit	P	7	7	(e) (5)	(e)	3 (5)	7
	Grand Rapids	P	11	9	(e) (5)	(e)	11 (5)	11
	Lansing	P	10	9	(e) (2)	(e)	21 (2)	16
	Marquette	P	15	13	(e) (3)	1	24 (3)	24
	Monroe	P	8	6	(e) (2)	(e)	0 (2)	2
	South Haven	P	NA	NA	(e) (5)	(e)	7 (5)	6
Minn:	Minneapolis[c]	P	12	9	0 (5)	0	13 (5)	7
	Bemidji	P	5	18	0	0	14	24
	Mankato	P	4	6	0	0	0	0
	Rochester	P	7	8	0	0	19	11
	Duluth	P	20	17	0	0	34	26
	Worthington	P	4	6	0	0	0	0
	Minneapolis	P	11	10	0	0	21	13
	Fergus Falls	P	5	8	0	0	0	11
	Little Falls	P	3	9	0	0	20	13
Miss:	Jackson[c]	P	15	12	0 (5)	0	15 (5)	12
Mo:	Kansas City[c]	P	10	8	0 (4)	0	8 (4)	2
	St. Louis[c]	P	11	8	0 (4)	0	7 (4)	2
Mont:	Helena[c]	P	5	5	0 (4)	0	6 (4)	5
Nebr:	Omaha[c]	P	8	6	0 (4)	0	0 (4)	1
Nev:	Las Vegas[c]	P	0	1	0 (5)	0	0 (5)	0

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for June 1970 and 12-month period, July 1969 through June 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
N.H:	Manchester[c]	P	10	8	0 (5)	0	16 (5)	16
N.J:	Trenton[c]	P	8	8	0 (5)	0	17 (5)	6
N. Mex:	Albuquerque[c]	P	4	3	0 (4)	0	0 (4)	0
N.Y:	Buffalo[c]	P	9	7	0 (4)	0	10 (4)	7
	New York City[c]	P	13	10	0 (5)	0	18 (5)	13
	Syracuse[c]	P	8	7	0 (4)	0	6 (4)	9
	Albany	P	5	4	0 (3)	0	0 (3)	0
	Buffalo	P	(e)	(e)	0	0	0	0
	Massena	P	7	6	0 (2)	0	26 (2)	0
	Newburg	P	13	7	0 (3)	0	0 (3)	0
	New York City	P	3	3	0 (2)	0	0 (2)	0
	Syracuse	P	6	6	0 (4)	0	0 (4)	0
N.C:	Charlotte[c]	P	10	11	0 (5)	0	15 (5)	12
N. Dak:	Minot[c]	P	2	9	0 (5)	0	14 (5)	15
Ohio:	Cincinnati[c]	P	9	8	0 (4)	0	10 (4)	4
	Cleveland[c]	P	9	9	0 (4)	0	11 (4)	5
Okla:	Oklahoma City[c]	P	7	6	0 (5)	0	12 (5)	8
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Oreg:	Portland[c]	P	8	6	0 (4)	0	5 (4)	6
	Baker	P	NA	3	(e)	(e)	(e)	(e)
	Coos Bay	P	NA	5	(e)	(e)	24	12
	Eugene	P	NA	2	(e)	(e)	(e)	6
	Medford	P	NA	2	(e)	(e)	16	8
	Portland composite	P	NA	4	(e)	(e)	11	7
	Portland local	P	NA	5	(e)	(e)	10	8
	Redmond	P	NA	2	(e)	(e)	(e)	3
	Tillamook	R	NA	6	(e)	(e)	(e)	13
Pa:	Philadelphia[c]	P	9	9	0 (4)	0	11 (4)	5
	Pittsburgh[c]	P	11	11	0 (5)	0	18 (5)	9
	Dauphin	P	9	7	0	3	13	11
	Erie	P	19	11	0	6	25	25
	Philadelphia	P	12	8	0	4	18	12
	Pittsburgh	P	20	12	0	3	24	19
R.I:	Providence[c]	P	12	9	0 (5)	0	25 (5)	15
S.C:	Charleston[c]	P	13	10	0 (5)	0	17 (5)	22
S.Dak:	Rapid City[c]	P	10	8	0 (5)	0	10 (5)	4
Tenn:	Chattanooga[c]	P	11	10	0 (5)	0	14 (5)	12
	Memphis[c]	P	10	9	0 (4)	0	11 (4)	5
	Chattanooga	P	11	12	3 (4)	0	18 (4)	13
	Clinton	P	16	14	0	0	22	12
	Knoxville	P	8	9	0 (2)	0	13 (2)	6
	Nashville	P	8	8	0	0	13	7
	Fayetteville	P	18	13	0 (2)	0	21 (2)	16
Tex:	Austin[c]	P	3	2	0 (3)	0	9 (3)	3
	Dallas[c]	P	9	6	0 (4)	0	11 (4)	7
	Amarillo	R	NS		NS		NS	
	Corpus Christi	R	NS		NS		NS	
	El Paso	R	NS		NS		NS	
	Fort Worth	R	NS		NS		NS	
	Harlingen	R	NS		NS		NS	
	Houston	R	NS		NS		NS	
	Lubbock	R	NS		NS		NS	
	Midland	R	NS		NS		NS	
	San Antonio	R	NS		NS		NS	
	Texarkana	R	NS		NS		NS	
	Uvalde	R	NS		NS		NS	
	Wichita Falls	R	NS		NS		NS	
Utah:	Salt Lake City[c]	P	4	4	0 (4)	0	10 (4)	3
Vt:	Burlington[c]	P	10	8	0 (4)	0	17 (4)	12
Va:	Norfolk[c]	P	10	10	0 (4)	0	14 (4)	8
Wash:	Seattle[c]	P	5	6	0 (4)	0	4 (4)	6
	Spokane[c]	P	5	6	0 (2)	0	2 (2)	2
	Benton County	R	NS	0	NS	0	NS	7
	Franklin County	R	0	2	0	0	0	3
	Sandpoint, Idaho	R	9	10	0	0	23	25
	Skagit County	R	7	6	0	0	0	12
W. Va:	Charleston	P	7	8	0 (4)	0	6 (4)	5
Wisc:	Milwaukee[c]	P	7	7	0 (4)	0	3 (4)	9
Wyo:	Laramie[c]	P	4	5	0 (2)	0	0 (2)	2
CANADA:								
Alberta:	Calgary	P	5	8	(d)		15	18
	Edmonton	P	7	7	(d)		NA	
British Colombia:	Vancouver	P	12	10	(d)		37	30
Manitoba:	Winnipeg	P	4	7	(d)		24	25

See footnotes at end of table.

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Table 3. Concentrations of radionuclides in milk for June 1970 and 12-month period, July 1969 through June 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
New Brunswick:	Fredericton	P	10	13	[d]		18	19
Newfoundland:	St. Johns	P	14	17	[d]		40	36
Nova Scotia:	Halifax	P	10	10	[d]		16	20
Ontario:	Ft. William	P	13	14	[d]		21	29
	Ottawa	P	4	7	[d]		13	13
	Sault Ste. Marie	P	13	14	[d]		43	30
	Toronto	P	3	4	[d]		8	10
	Windsor	P	5	5	[d]		13	10
Quebec:	Montreal	P	6	8	[d]		16	17
	Quebec	P	8	10	[d]		36	26
Saskatchewan:	Regina	P	6	7	[d]		15	14
	Saskatoon	P	12	8	[d]		16	11
CENTRAL AND SOUTH AMERICA:								
Colombia:	Bogota	P	2	2	0	0	0	3
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	2	0	0	0	0	0
Jamaica:	Montego Bay	P	9	5	0	5	155	84
Venezuela:	Caracas	P	0	2	0	0	0	0
Canal Zone:	Cristobal[c]	P	2	1	0 (5)	0	12 (5)	10
Puerto Rico:	San Juan[c]	P	4	3	0 (3)	0	9 (3)	7
PMN Network average[f]			8	7	0	0	11	8

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or national network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote [c].

NA, no analysis.
NS, no sample.

majority of the stations for June 1970 were below the respective practical reporting levels. Table 4 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (see table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 21 pCi/liter in the United States for the month of June 1970; and the highest 12-month average was 19 pCi/liter (Del Norte, Calif.), representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 98 pCi/liter in the United States for the month of June 1970; and the highest 12-month average was 73 pCi/liter (southeast Florida), representing 2.0 percent

Table 4. Strontium-89 in milk, June 1970

Sampling location	Radionuclide concentration (pCi/liter)
Calif., Del Norte (State)	12
Iowa, Des Moines (PMN)	6
La., New Orleans (PMN)	11
Minn., Minneapolis (PMN)	8
Mo., St. Louis (PMN)	6
N.Y., Abany (State)	8 (3 samples)
Massena (State)	7 (2 samples)
Syracuse (State)	6
Okla., Oklahoma City (PMN)	7
Tenn., Fayetteville (State)	6
Tex: Dallas (PMN)	9
Wash., Seattle (PMN)	7

XUM

of the value presented in this report using the recommendations given in the *Federal Radiation Council* reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level.

The Canadian Department of National Health and Welfare, as of May 1970, have changed their analysis pattern. Monthly samples will be collected and composited for quarterly analysis of strontium-90.

Acknowledgement

Appreciation is expressed to the personnel of the following health agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Issue
California Diet Study	October–December 1968 and January–March 1969	May 1970
Connecticut Diet Study	July–December 1968 and January–June 1969	February 1970
Radionuclides in Institutional Diet Samples, *PHS*	October–December 1969 and annual summary 1969	August 1970
Strontium-90 in Tri-City Diets, *HASL*	June–December 1969	June 1970

XUM

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Kansas	January–December 1969	September 1970
Minnesota	January–June 1969	January 1970
New York	January–June 1969	June 1970
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium Network	July–December 1969	July 1970
Washington	July 1967–June 1968	June 1969

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(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
Tritium in Precipitation	July–December 1969	July 1970

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1. Radiation Alert Network June 1970

National Air Pollution Control Administration
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Air Pollution Control Administration officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality Emission Data, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during June 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting stations except the Denver, Colo., station which reported 23 pCi/m^3 on June 2, 1970. The 29-hour field reading had decreased to 5 pCi/m^3. This sample was analyzed at NERHL for specific nuclides. No unusual radioactivity above background was detected on this sample at the laboratory.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, June 1970

Station location		Air surveillance				Last profile in RHD&R	Precipitation				
		Number of samples	Gross beta radioactivity (pCi/m³)				Number of samples	Total depth (mm)	Field estimation of deposition		
			Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	11	0	3	Oct 70	5	176	5	176	80
Alaska:	Adak	[b]				Oct 70	[c]				
	Anchorage	12	0	0	0	Aug 69	[c]				
	Attu Island	2	1	0	0	Mar 69	[c]				
	Fairbanks	20	1	0	0	Sept 69	9	36	9	36	19
	Juneau	6	3	1	2	Aug 70	2	21	2	21	2
	Kodiak	2	0	0	0	Sept 70	[c]				
	Nome	15	3	0	1	May 69	[c]				
	Point Barrow	10	0	0	0	Apr 69	[c]				
	St. Paul Island	[b]				June 69	[c]				
Ariz:	Phoenix	13	6	2	3	Aug 70	[c]				
Ark:	Little Rock	13	3	1	2	Aug 69	[c]				
Calif:	Berkeley	21	1	0	0	Sept 70	1	14	1	14	1
	Los Angeles	21	2	1	1	May 69	[c]				
C.Z:	Ancon	17	0	0	0	Sept 70	[c]				
Colo:	Denver	21	23	2	7	Sept 70	7	78	[d]		
Conn:	Hartford	22	2	0	1	Sept 69	5	67	4	44	5
Del:	Dover	21	1	0	1	July 69	[c]				
D.C:	Washington	26	2	0	1	Apr 69	[c]				
Fla:	Jacksonville	22	2	0	1	Aug 69	7	105	7	105	32
	Miami	17	3	0	0	Sept 69	9	135	135	9	0
Ga:	Atlanta	21	2	1	1	June 69	2	158	2	158	67
Guam:	Agana	[b]				July 69	[c]				
Hawaii:	Honolulu	23	1	0	0	Mar 69	1	5	[d]		
Idaho:	Boise	21	4	1	2	Mar 69	4	49	4	49	5
Ill:	Springfield	12	3	0	1	Apr 69	[c]				
Ind:	Indianapolis	[b]				June 69	[c]				
Iowa:	Iowa City	13	3	1	1	Sept 70	5	127	5	127	15
Kans:	Topeka	22	3	0	2	Aug 69	11	185	11	185	0
Ky:	Frankfort	14	4	0	2	Apr 69	[c]				
La:	New Orleans	21	1	0	0	Apr 69	4	136	[d]		
Maine:	Augusta	22	8	0	2	Aug 70	5	93	5	93	0
Md:	Baltimore	22	2	0	1	Sept 69	7	63	7	63	15
	Rockville	14	2	0	1	Mar 69	[c]				
Mass:	Lawrence	22	3	0	1	Sept 70	4	117	4	117	4
	Winchester	21	3	0	1	Oct 70	3	108	3	108	0
Mich:	Lansing	20	2	0	1	Mar 69	7	85	7	85	11
Minn:	Minneapolis	21	3	0	1	July 69	5	72	5	72	25
Miss:	Jackson	15	2	0	1	Aug 70	4	193	4	193	22
Mo:	Jefferson City	21	2	0	1	June 69	9	173	9	173	1
Mont:	Helena	14	3	1	1	Oct 70	2	6	2	6	0
Nebr:	Lincoln	17	6	1	3	June 69	4	56	4	56	19
Nev:	Las Vegas	21	3	1	2	Sept 69	[c]				
N.H:	Concord	[b]				Apr 69	[c]				
N.J:	Trenton	20	2	0	1	Aug 70	10	105	10	105	16
N. Mex:	Santa Fe	17	3	0	1	Oct 70	3	6	3	6	1
N.Y:	Albany	16	2	0	1	June 69	2	34	2	34	11
	Buffalo	21	3	1	1	Sept 70	[c]				
	New York City	[b]				Oct 70	[c]				
N.C:	Gastonia	15	11	1	5	Sept 70	1	15	[d]		
N. Dak:	Bismarck	21	4	1	2	Apr 69	7	111	7	111	4
Ohio:	Cincinnati	[b]				July 69	[c]				
	Columbus	5	4	1	3	Aug 70	[c]				
	Painesville	21	4	0	2	Sept 69	9	73	9	73	17
Okla:	Oklahoma City	8	3	1	2	Mar 69	1	9	1	9	0
	Ponca City	21	4	1	2	Sept 69	8	65	8	65	1
Oreg:	Portland	21	2	0	1	June 69	4	13	4	13	2
Pa:	Harrisburg	16	2	0	1	June 69	2	41	2	41	11
P.R:	San Juan	[b]				Aug 70	[c]				
R.I:	Providence	21	2	0	1	Mar 69	3	39	3	39	4
S.C:	Columbia	16	3	0	1	Oct 70	3	41	3	41	0
S. Dak:	Pierre	7	7	2	4	Aug 70	[c]				
Tenn:	Nashville	22	3	0	1	Mar 69	7	119	7	119	6
Tex:	Austin	15	6	1	3	July 69	[c]				
	El Paso	[b]				Apr 69	[c]				
Utah:	Salt Lake City	30	2	0	1	May 69	6	39	6	39	0
Vt:	Barre	21	4	0	2	Aug 69	6	90	6	90	13
Va:	Richmond	22	2	0	1	Aug 69	3	36	3	36	4
Wash:	Seattle	20	1	0	0	Aug 69	2	9	[d]		
	Spokane	21	2	0	1	July 69	[c]				
W. Va:	Charleston	21	4	1	2	Oct 70	7	51	7	51	10
Wisc:	Madison	22	3	0	1	Aug 69	7	120	7	120	19
Wyo:	Cheyenne	22	8	0	3	Sept 69	4	67	4	67	9
Network summary		1,142	23	0	1		6	86	5	79	12

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

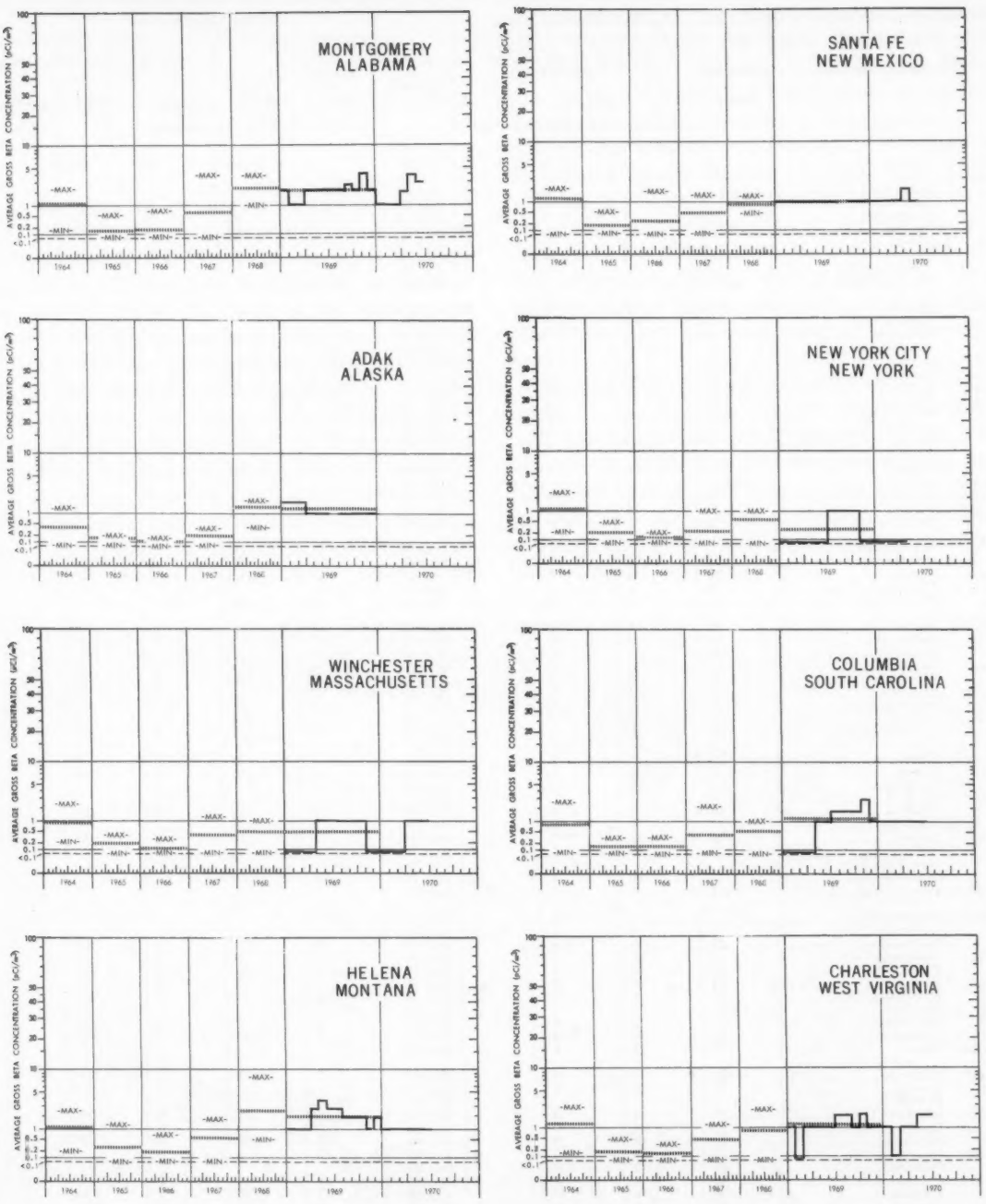

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–June 1970

2. Canadian Air and Precipitation Monitoring Program[1], June 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health and Data Reports.*

Surface air and precipitation data for June 1970 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, June 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	1.0	0.2	0.6	31	4.9
Coral Harbour	29	.3	.0	.1	39	1.6
Edmonton	30	.7	.0	.4	124	14.9
Ft. Churchill	30	.5	.0	.2	249	3.3
Fredericton	30	.7	.0	.3	111	10.6
Goose Bay	30	.6	.0	.2	42	4.3
Halifax	29	.6	.0	.2	78	8.9
Inuvik	30	.5	.0	.2	92	2.5
Montreal	30	.8	.1	.4	236	11.4
Moosonee	30	.6	.1	.3	113	8.8
Ottawa	30	.7	.0	.4	66	1.8
Quebec	30	.6	.0	.3	146	13.2
Regina	30	.9	.0	.4	135	10.3
Resolute	29	.3	.0	.1	24	.4
St. John's, Nfld.	29	.4	.0	.2	46	3.5
Saskatoon	30	.8	.1	.4	109	18.7
Sault Ste. Marie	29	1.0	.1	.4	52	3.1
Thunder Bay	29	.7	.1	.3	166	7.9
Toronto	30	1.0	.1	.5	207	7.7
Vancouver	23	.6	.1	.3	122	4.7
Whitehorse	30	.5	.0	.2	60	.9
Windsor	30	1.0	.1	.4	34	2.3
Winnipeg	21	.8	.2	.4	225	11.3
Yellowknife	30	.7	.1	.3	242	3.7
Network summary	698	1.0	0.0	0.3	119	6·7

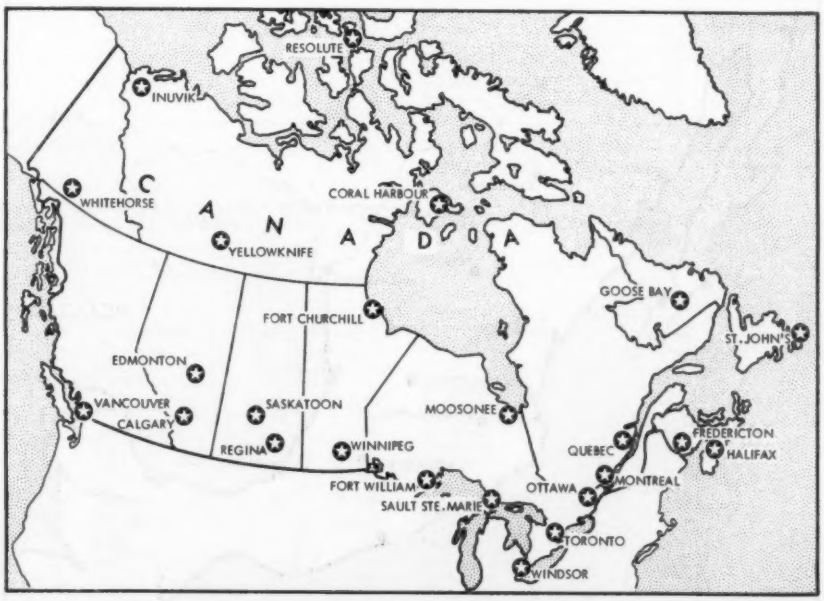

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program January–June 1970

National Commission of Nuclear Energy
México, D. F.

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguirdad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Prevision del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency, 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity concentration at each station (*6*).

The maximum, minimum, and average beta radioactivity in surface air during January through June 1970 are presented in tables 3 through 8.

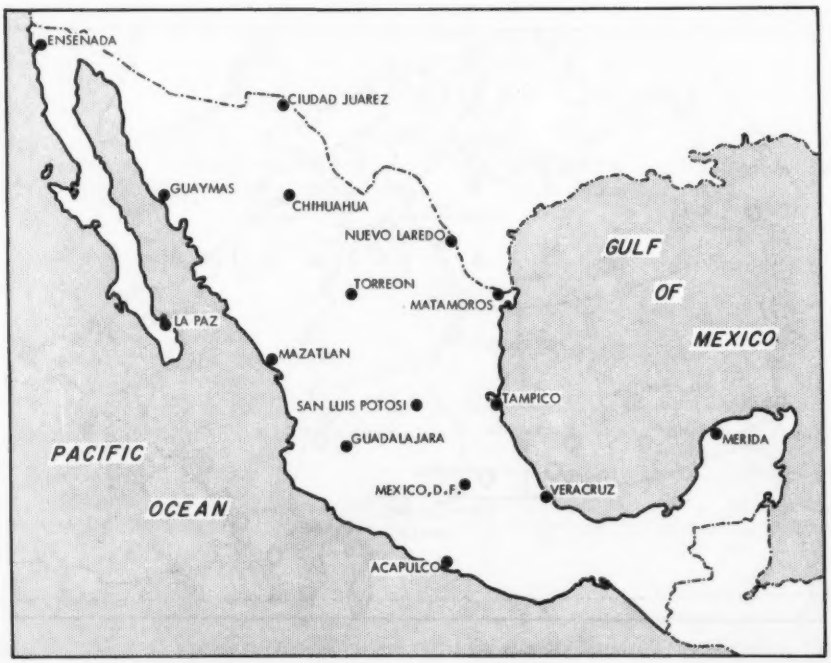

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, January 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Acapulco	NS			
Chihuahua	9	0.29	0.12	0.18
Ciudad Juarez	NS			
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	17	.19	.09	.12
Matamoros	NS			
Mazatlán	NS			
Mérida	2	.14	.09	
México, D.F.	8	.23	.12	.15
Nuevo Laredo	7	.16	.06	.11
San Luis Potosí	NS			
Tampico	NS			
Torreón	14	.34	.11	.23
Veracruz	NS			

[a] Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 4. Mexican gross beta radioactivity of airborne particulates, February 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	NS			
Chihuahua	8	0.38	0.11	0.21
Ciudad Juarez	NS			
Ensenada	7	.24	.05	.13
Guadalajara	NS			
Guaymas	NS			
La Paz	13	.40	.11	.22
Matamoros	NS			
Mazatlán	NS			
Mérida	NS			
México, D.F.	7	.23	<.03	.09
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	NS			
Veracruz	14	.23	.06	.12

NS, no sample, station temporarily shutdown.

Table 5. Mexican gross beta radioactivity of airborne particulates, March 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Acapulco	NS			
Chihuahua	NS			
Ciudad Juarez	6	0.29	0.08	0.16
Ensenada	6	.21	.13	.16
Guadalajara	NS			
Guaymas	NS			
La Paz	2	.28	.10	
Matamoros	NS			
Mazatlán	NS			
Mérida	14	.35	.12	.22
México, D.F.	NS			
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	15	.39	.07	.21
Veracruz	3	.17	.09	

[a] Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 6. Mexican gross beta radioactivity of airborne particulates, April 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Acapulco	NS			
Chihuahua	NS			
Ciudad Juarez	NS			
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	4	0.61	0.42	0.45
Matamoros	NS			
Mazatlán	NS			
Mérida	2	.68	.37	
México, D.F.	NS			
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	7	.90	.34	.57
Veracruz	6	.92	.28	.49

[a] Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 7. Mexican gross beta radioactivity of airborne particulates, May 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Acapulco	NS			
Chihuahua	NS			
Ciudad Juarez	11	0.87	0.17	0.61
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	2	.63	.02	
Matamoros	NS			
Mazatlán	NS			
Mérida	1	.51		
México, D.F.	NS			
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	NS			
Veracruz	1	.12		

[a] Average not calculated for less than 5 samples.
NS, no sample, station temporarily shutdown.

Table 8. Mexican gross beta radioactivity of airborne particulates, June 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Acapulco	NS			
Chihuahua	10	0.66	0.06	0.42
Ciudad Juarez	NS			
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	NS			
Matamoros	NS			
Mazatlán	NS			
Mérida	8	.70	.24	.38
México, D.F.	NS			
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	6	.43	.08	.22
Veracruz	NS			

NS, no sample, station temporarily shutdown.

XUM

4. Pan American Air Sampling Program June 1970

Pan American Health Organization and
U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The June 1970 air monitoring results from the participating countries are given in table 9.

The higher value reported for LaPaz, Bolivia, on June 30 is attributed to recent foreign testing.

Figure 5. Pan American Air Sampling Program stations

Table 9. Summary of gross beta radioactivity in Pan American surface air, June 1970

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	15	0.57	0.01	0.10
Bolivia:	La Paz	15	14.7	.14	2.42
Chile:	Santiago	29	.60	.05	.28
Colombia:	Bogota	21	.74	.01	.17
Ecuador:	Cuenca	NS			
	Guayaquil	21	.76	.01	.32
	Quito	NS			
Guyana:	Georgetown	14	.33	.02	.15
Jamaica:	Kingston	NS			
Peru:	Lima	24	.95	.05	.35
Venezuela:	Caracas	17	.74	.01	.24
West Indies:	Trinidad	NS			
Pan American summary		156	14.7	0.01	0.45

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

Subsequent samples from this and other stations collected early in the month of July also reflect the increase. Gamma analysis of the filters indicate that the radioactivity is due primarily to barium-lanthanum-140.

5. Plutonium in Airborne Particulates April–December 1969

Bureau of Radiological Health
U.S. Public Health Service

The Radiation Alert Network (RAN) of the Bureau of Radiological Health, Public Health Service, routinely analyzes airborne particulate samples from 11 selected RAN stations for plutonium. The plutonium analyses were initiated in November 1965 and the results through March 1969 have been previously reported (*7–19*).

One-half of each individual air filter from the selected stations is sent to the Northeastern Radiological Health Laboratory, Winchester, Mass. The laboratory analyzes a composite of these samples for each station on a quarterly basis. During this period, however, the samples from Denver and Gastonia were composited and analyzed on a monthly basis and an arithmetical average reported for the quarter.

The results for April through December 1969 are presented in table 10. ND (nondetectable) has been used to indicate samples containing

Table 10. Plutonium in airborne particulates for April-December 1969

1969	Anchorage	Phoenix	Denver[a]	Honolulu	New Orleans	Rockville	Buffalo	Gastonia[a]	Pierre	Austin	Seattle
Plutonium-238 (fCi/m³)											
April–June	0.012	0.049	0.030	0.012	0.026	0.018	0.027	0.019	0.020	0.023	0.012
July–September	.008	.006	.015	.004	.008	.007	.012	.006	.012	.009	.006
October–December	.005	.008	.006	.003	.004	.006	.003	.003	.007	.013	.002
Plutonium-239 (fCi/m³)											
April–June	.036	.240	.108	.041	.089	.074	.077	.050	.110	.089	.048
July–September	.034	.061	.064	.025	.060	.062	.073	.038	.045	.050	.034
October–December	.016	.057	.035	.019	.027	.021	.022	.016	.066	.040	.014
$^{239}Pu/^{238}Pu$											
April–June	3.00	4.90	3.60	3.42	3.42	4.11	2.85	2.63	5.50	3.87	4.00
July–September	4.25	10.17	4.27	6.25	7.50	8.86	6.08	6.33	3.75	5.56	5.67
October–December	3.20	7.13	5.83	6.33	6.75	3.50	7.33	5.33	9.43	3.08	7.00

[a] Average of three individual monthly results.

plutonium-238 or plutonium-239 less than or equal to the appropriate minimum detectable activities (0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively). The volume of air sampled varies, generally ranging from 20,000 to 30,000 cubic meters of air per month.

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XUM

Surface Air Sampling Program - 80th Meridian Network January-December 1966[1]

Health and Safety Laboratory
Atomic Energy Commission

The Health and Safety Laboratory began its Surface Air Sampling Program in January 1963, as a continuation of the 80th Meridian Program conducted by the U.S. Naval Research Laboratory. The objectives of this program are to determine the concentrations of radioactivity in surface air in both hemispheres as a function of latitude and season, and to interpret these data in terms of the dominant meteorological and physical processes which are operative.

The basic network consists of a line of sites approximately along the 80th Meridian extending from about 76° N to 63° S latitudes (figure 1). Since 1963, a number of sites have been added to investigate the possible effects of longitude, elevation and proximity to coastlines; and in late 1965, samplers were placed on four Atlantic Ocean weather ships to extend the surface air study over the marine environment. The Environmental Science Services Administration, Department of Commerce, maintains a collection site at the Amundson Scott Station in Antarctica. The air filter samples from this site are also included in the HASL program.

Sampling and analytical procedures

Approximately 1,400 cubic meters of ambient air per day are drawn through and 8-inch diameter microsorban filter for the land stations. For the ocean stations, about 2,200 cubic meters of air per day are filtered by an 8- by 10-inch microsorban filter. Each filter is changed on the 1st, 8th, 15th, and 22nd of the month or more frequently if the filter becomes clogged with debris suspended in the air. Under normal conditions, the filters from each station are compressed into a monthly composite and the gamma spectrum of the composite is obtained by an 8- by 4-inch NaI (Tl) crystal, approximately 2 weeks after the last collection in the month.

The integrated response between 100 keV and 3.0 MeV is corrected by the average detection efficiency (35 percent) of the gamma photons present in fallout and the total gamma radioactivity is reported in units of photons/min/1,000 m^3. Average monthly gamma concentrations are calculated by weighting the concentrations in each sampling interval by the relative period of time in the interval. After the gamma measurements have been completed, monthly composites from each site are submitted to contractor laboratories for radiochemical analyses. Since the last major nuclear weapon test series occurred at the end of 1962, only the longer lived artificially produced radionuclides were present in the filters analyzed prior to May 1966. Consequently, emphasis was given to the determination of manganese-54, iron-55, strontium-90, cadmium-109, cesium-137, cerium-144, plutonium-238, and plutonium-239. Strontium-90, zirconium-95, and cerium-141 were analyzed in samples collected after the foreign nuclear test of May 1966.

The longer lived fission products and plutonium-239 concentrations should describe the general distribution in surface air of all previous nuclear

[1] Summarized from "Fallout Program Quarterly Summary Report," HASL-184, 227, available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

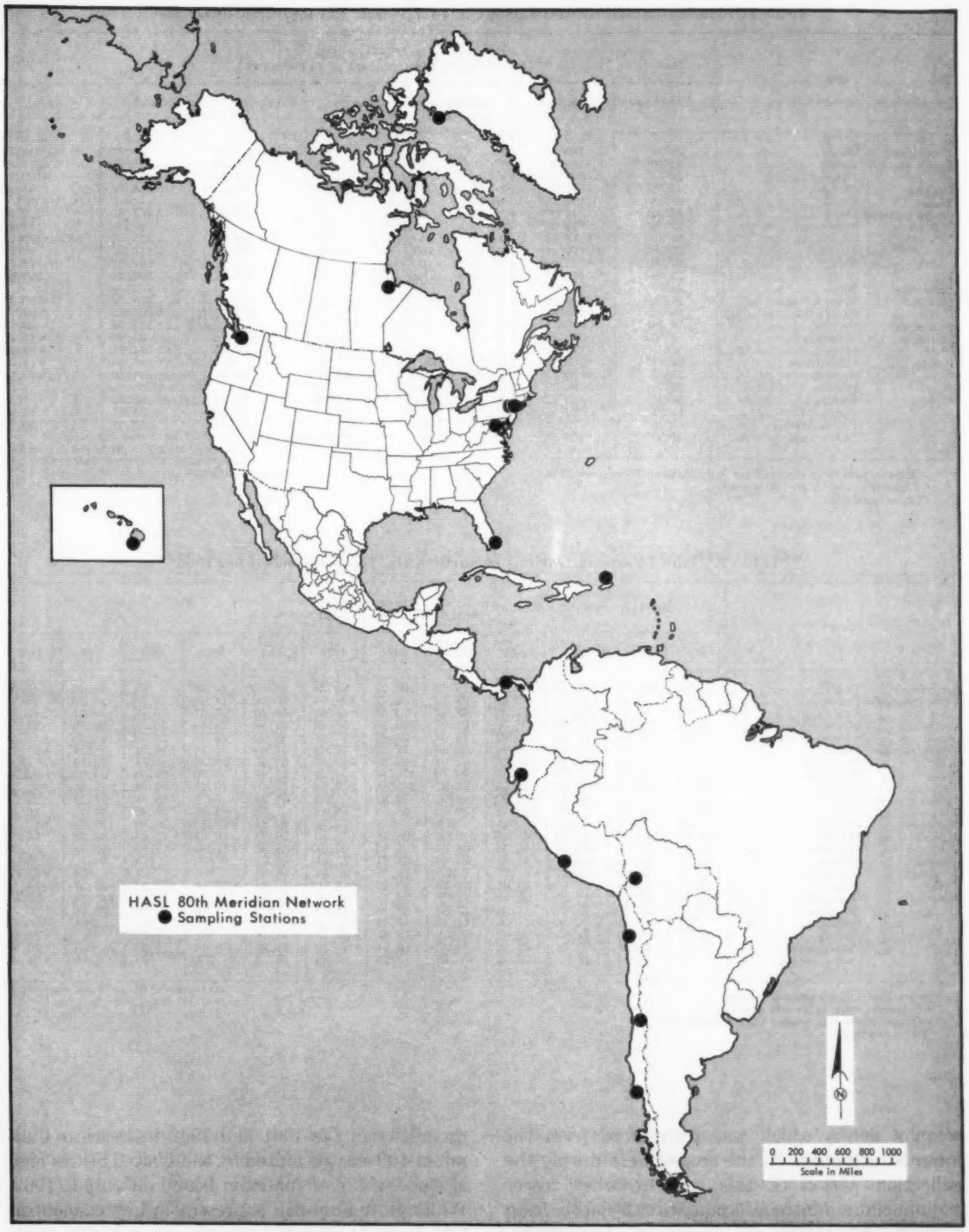

Figure 1. 80th Meridian Network sampling stations

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Table 1. Manganese-54 concentrations in surface air, January–December 1966[a]

Site		Latitude	Longitude	Elevation (meters)	Concentration (dpm/1,000 standard m³ at midmonth) January	February	March	April
Greenland:	Thule	76°36′	68°35′	259	NA	221.34	259.95	215.01
Ocean station:	Bravo	56°30′	51°00′	0	NA	80.20	128.02	215.02
	Charlie	52°45′	35°30′	0		50.29	128.95	126.95
Ontario:	Moosonee	51°16′	80°30′	10	87.28	105.98	139.96	88.99
Wash:	Seattle	47°36′	122°20′	3				
Ocean station:	Delta	44°00′	41°00′	0	NA	97.87	151.90	125.05
N.J:	Westwood	41°00′	74°01′	38	NA	NA	NA	147.50
N.Y:	New York City	40°48′	73°58′	38	82.52	83.10	173.61	135.25
Va:	Sterling	38°58′	77°25′	76	72.04	88.94	146.41	84.24
Ocean station:	Echo	35°00′	48°00′	0	NA	212.11	182.02	143.05
Fla:	Miami	25°49′	80°17′	4	122.30	137.21	237.65	250.81
Bahamas:	Bimini	25°46′	79°22′	3				
Hawaii:	Mauna Loa	19°28′	155°36′	3,401	170.29	146.25	307.51	189.44
P.R:	San Juan	18°26′	66°00′	10	48.59	119.45	203.42	97.38
Panama:	Balboa	8°58′	79°34′	23	49.36	88.99	127.03	68.75
Ecuador:	Guayaquil	2°10′	79°52′	7	[b] 17.94	[b] 22.18	[b] 35.41	[b] 15.26
Peru:	Lima	12°01′	77°08′	13	47.38	69.55	44.11	[b] 12.92
Bolivia:	Chacaltaya	16°21′	68°07′	5,220	[b] 27.05	NA	[b] 49.15	[b] 45.32
Chile:	Antofagasta	23°37′	70°16′	31	46.54	48.69	[b] 31.42	[b] 35.82
	Portillo	32°50′	70°08′	2,850				
	Santiago	33°27′	70°42′	520	57.91	64.35	38.96	NA
	Puerto Montt	41°27′	72°57′	7	31.16	41.18	33.87	45.65
	Punta Arenas	53°08′	70°53′	35	27.74	[b] 15.44	[b] 33.41	[b] 20.90
	Pedro Aquire Cerda	62°56′	60°36′	16				

[a] No analyses were reported for May through December 1966.
[b] Counting error is 20–100 percent.
NA, no analysis.

Table 2. Iron-55 concentrations in surface air, January–December 1966

Site		Concentration (dpm/1,000 standard m³ at midmonth) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	NA	189.81	290.40	147.99	129.47	106.27	89.24	76.53	14.45	NA	28.45	47.92
Ocean station:	Bravo	NA	61.40	130.96	82.32	87.72	62.57	124.04	40.29	14.80	13.77	28.26	18.27
	Charlie	NA	69.59	169.96	177.09	67.87	70.33	47.65	58.49	16.37	9.80	19.61	19.64
Ontario:	Moosonee	76.54	94.98	176.86	105.05	109.95	126.75	152.49	63.38	33.59	26.33	25.70	34.52
Wash:	Seattle	NA	104.88	220.44	100.92	149.04	91.86	81.48	45.60	25.55	23.72	32.65	[a] 10.31
Ocean station:	Delta	75.50	93.89	166.40	133.74	138.89	94.26	72.82	97.40	31.16	[a] 18.52	NA	[a] 27.78
N.J:	Westwood	73.35	77.53	136.13	147.50	162.94	203.09	159.13	60.45	39.32	NA	25.88	NA
N.Y:	New York City	99.58	86.62	208.75	139.51	290.70	276.16	253.48	87.97	34.80	24.54	63.57	82.78
Va:	Sterling	83.22	106.39	228.70	115.53	198.81	243.38	217.91	117.20	[a] 20.63	54.68	[a] 15.04	[a] 46.91
Ocean station:	Echo	NA	161.97	254.13	163.00	199.01	67.81	NA	51.95	(b)	18.88	27.22	22.51
Fla:	Miami	146.01	125.58	312.94	264.32	130.12	95.95	75.49	[a] 1.39	[a] 5.55	26.46	[a] 34.49	79.17
Bahamas:	Bimini	NA	NA	NA	NA	NA	NA	46.72	92.25	[a] 40.55	130.95	129.71	[a] 70.15
Hawaii:	Mauna Loa	191.67	220.95	295.90	244.10	210.00	198.26	157.19	59.23	[a] 10.51	[a] 17.61	[a] 41.32	54.50
P.R:	San Juan	56.78	134.04	270.94	115.74	108.63	101.54	66.01	[b] 68.36	[a] 14.93	[a] 7.69	[a] 19.14	41.26
Panama:	Balboa	55.75	78.84	141.47	84.64	35.14	91.71	22.91	[a] 6.01	NA	NA	(b)	(b)
Ecuador:	Guayaquil	[a] 12.71	23.82	[a] 16.03	[a] 31.75	NA	[a] 15.27	[a] 26.04	40.96	NA	NA	NA	[a] 25.92
Peru:	Lima	55.11	53.91	61.15	[a] 33.85	31.71	29.92	66.10	[a] 54.66	[a] 27.91	172.25	[a] 28.57	130.10
Bolivia:	Chacaltaya	29.45	25.21	31.27	[a] 22.84	23.77	52.12	61.90	168.80	157.93	55.37	141.74	96.84
Chile:	Antofagasta	55.97	48.69	38.65	44.23	27.32	[a] 23.46	54.97	NA	[a] 8.79	45.94	108.79	(b)
	Portillo	NA	NA	NA	NA	144.33	40.94	312.00	214.66	NA	NA	NA	590.91
	Santiago	77.97	138.49	124.85	[a] 98.07	NA	[a] 18.80	[a] 61.85	[a] 35.28	NA	[a] 39.14	(b)	[a] 76.47
	Puerto Montt	39.77	48.34	50.12	[a] 42.59	16.95	10.84	20.22	37.62	[a] 6.26	14.25	NA	[a] 70.93
	Punta Arenas	NA	49.86	45.73	[a] 23.51	[a] 7.83	11.29	15.83	19.33	NA	NA	NA	[a] 31.38

Errors are less than 20 percent except:
[a] Counting error is 20–100 percent.
[b] Counting error is greater than 100 percent.
NA, no analysis.

weapon debris which was transferred from the lower stratosphere to the troposphere during the collection period of this report. Other tracer radionuclides can be associated with debris from a single detonation or a series of detonations. Manganese-54 and iron-55 were produced in large quantities in the 1961 and 1962 test series. Cadmium-109 was generated by the United States high altitude test over Johnston Island on July 9, 1962. While plutonium-238 is present in low concentrations in nuclear weapons debris, about 17,000 curies of plutonium-238 were disseminated at high alti-

Table 3. Strontium-89 concentrations in surface air, January–December 1966[a]

Site		Concentration (dpm/1,000 standard m³ at midmonth)							
		May	June	July	August	September	October	November	December
Greenland:	Thule	[b] 85.15	NA	7.24	4.49	8.65	[b] 4.15	107.61	34.47
Ocean station:	Bravo	2.16	4.84	[b] 2.20	9.20	NA	NA	14.30	10.49
	Charlie	NA	NA	9.90	6.27	[b] 1.44	[b] .81	36.32	12.12
Ontario:	Moosonee	NA	23.00	NA	5.98	NA	NA	49.44	13.95
Wash:	Seattle	NA	4.62	9.08	14.55	[b] 11.41	NA	28.35	5.28
Ocean station:	Delta	NA	14.20	20.60	6.45	NA	[c]	36.11	13.42
N.Y:	New York City	26.71	44.04	28.43	9.91	5.72	4.81	70.22	56.48
Va:	Sterling	20.86	60.52	51.00	7.40	[b] 5.82	NA	56.56	[b] 10.77
Ocean station:	Echo	[b] .66	15.94	NA	5.89	NA	[c]	30.89	NA
Fla:	Miami	101.41	95.19	22.65	10.96	[b] 1.63	11.17	160.76	NA
Bahamas:	Bimini	NA	NA	[b] 26.09	6.28	15.00	[b] 16.67	161.34	23.91
Hawaii:	Mauna Loa	108.93	332.40	40.07	6.55	[b] 4.12	NA	[b] 14.19	NA
P.R:	San Juan	40.05	70.44	30.32	NA	NA	[c]	21.72	NA
Panama:	Balboa	18.51	9.15	8.14	4.27	3.54	5.43	14.57	[b] 7.11
Ecuador:	Guayaquil	NA	2.96	209.90	5.29	10.81	133.25	197.67	85.29
Peru:	Lima	[b] .56	5.35	481.84	40.69	[b] 23.28	976.08	391.16	100.35
Bolivia:	Chacaltaya	NA	34.07	1,674.60	74.44	1,103.45	1,329.11	669.57	168.42
Chile:	Antofagasta	NA	NA	242.83	NA	254.67	763.34	149.70	73.09
	Portillo	7.76	NA	680.00	128.27	NA	NA	NA	421.21
	Santiago	NA	NA	225.54	40.18	73.37	186.16	148.64	78.99
	Puerto Montt	NA	NA	1.85	20.96	4.68	17.89	60.75	26.19
	Punta Arenas	.70	NA	.99	4.01	4.36	12.53	16.49	6.78

[a] No analyses were reported for January through April 1966.
Errors are less than 20 percent except:
[b] Counting error is 20–100 percent.
[c] Counting error is greater than 100 percent.
NA, no analysis.

Table 4. Strontium-90 concentrations in surface air, January–December 1966

Site		Concentration (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	NA	23.63	23.89	NA	13.19	12.80	7.12	5.74	4.92	4.54	2.54	5.11
Ocean station:	Bravo	NA	8.80	12.60	20.91	5.99	7.05	3.79	4.08	[a] 1.95	.91	1.38	1.69
	Charlie	NA	5.26	13.70	15.31	8.42	5.45	3.30	4.33	2.17	1.62	2.39	1.48
Ontario:	Moosonee	8.88	11.08	11.46	11.90	15.93	13.55	13.66	5.53	3.79	2.48	3.48	2.17
Wash:	Seattle	7.40	8.86	12.89	14.00	9.85	9.21	5.59	[a] 5.06	3.29	2.14	2.96	2.18
Ocean station:	Delta	NA	9.18	16.39	13.50	14.79	11.49	7.15	3.20	4.16	2.23	2.70	1.63
N.J:	Westwood	11.22	12.52	20.53	17.57	22.98	31.74	19.64	8.87	5.49	NA	3.74	NA
N.Y:	New York City	9.46	7.85	17.99	17.13	24.86	23.77	18.46	8.95	6.00	4.27	4.56	4.23
Va:	Sterling	9.19	10.32	15.87	12.28	25.54	24.68	16.64	8.26	4.97	4.12	3.94	3.97
Ocean station:	Echo	NA	17.01	17.60	19.51	22.22	5.30	NA	5.04	4.33	2.03	2.40	1.71
Fla:	Miami	12.35	11.68	19.95	29.46	[b]	11.47	5.61	.99	1.73	2.86	6.77	4.82
Bahamas:	Bimini	NA	NA	NA	NA	NA	NA	14.53	8.64	3.55	6.81	8.53	4.95
Hawaii:	Mauna Loa	16.23	16.88	33.17	28.17	28.32	19.83	13.73	5.19	3.90	2.21	3.95	7.25
P.R:	San Juan	5.63	12.98	15.81	12.00	11.22	13.47	5.75	5.39	2.70	1.14	2.87	2.92
Panama:	Balboa	5.93	9.33	10.87	8.46	2.89	.67	.99	1.06	[a] .22	[a] .18	1.66	1.64
Ecuador:	Guayaquil	1.88	2.19	1.22	1.16	1.07	1.54	2.33	3.27	1.61	2.06	5.38	3.18
Peru:	Lima	7.71	7.07	4.69	3.64	2.51	2.42	6.44	4.58	6.53	11.10	10.68	6.33
Bolivia:	Chacaltaya	3.31	1.96	3.11	2.31	2.86	5.42	13.10	5.68	[a] 25.41	9.37	13.48	7.61
Chile:	Antofagasta	6.76	5.52	3.29	2.96	2.57	2.41	5.36	3.96	4.93	11.23	4.67	3.39
	Portillo	NA	NA	NA	NA	7.51	4.64	[a] 130.29	24.35	NA	NA	NA	40.91
	Santiago	8.31	10.00	5.21	[a] 4.41	3.06	2.40	6.00	4.85	3.40	4.65	7.16	5.13
	Puerto Montt	4.47	5.09	3.04	2.75	1.64	[a] 1.46	1.35	3.06	1.64	1.85	4.29	1.60
	Punta Arenas	2.60	2.48	2.89	1.72	1.19	1.19	1.42	1.84	1.24	.67	[a] .90	1.11

Errors are less than 20 percent except:
[a] Counting error is 20–100 percent.
[b] Counting error is greater than 100 percent.
NA, no analysis.

tude in the stratosphere on April 21, 1964 during the reentry burnup of a SNAP-9A power source.

During 1966, Food, Chemical, and Research Laboratories, Incorporated (FCRL) of Seattle, Wash., performed the analyses of most of the samples in this program. Isotopes, Incorporated of Westwood, N. J., analyzed most of the samples collected at Westwood, N.J., and a few samples from Chacaltaya, Bolivia, Antotagasta and Santiago, Chile. Previous reports containing data on the HASL Surface Air Sampling Program are given in references *1–7*.

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Table 5. Zirconium-95 concentrations in surface air, January–December 1966[a]

Site		Concentration (dpm/1,000 standard m³ at midmonth)							
		May	June	July	August	September	October	November	December
Greenland:	Thule	[b] 4.71	34.10	9.36	2.98	2.25	[b] 1.39	30.14	12.35
Ocean station:	Bravo	[b] 2.65	7.20	13.50	86.31	2.72	3.75	12.29	[b] 11.36
	Charlie	5.34	6.60	10.80	4.08	2.46	[b] 1.07	23.66	[b] 4.83
Ontario:	Moosonee	8.80	25.50	12.68	2.26	[b] 2.15	2.91	33.15	8.90
Wash:	Seattle	52.78	16.26	11.58	4.18	[b] 2.06	1.46	17.19	2.51
Ocean station:	Delta	8.64	26.78	34.97	1.79	2.73	6.07	36.89	[b] 4.07
N.Y:	New York City	44.68	53.37	33.92	5.01	2.99	6.11	113.14	15.77
Va:	Sterling	29.83	78.44	251.24	6.27	[b] 3.32	[b] 1.36	45.48	12.24
Ocean station:	Echo	37.98	20.78	NA	3.29	1.70	[b] 1.24	24.96	[c]
Fla:	Miami	59.06	120.25	16.10	33.91	[b] .92	6.33	190.82	10.39
Bahamas:	Bimini	NA	NA	107.81	12.29	[b] 3.94	9.48	185.30	11.35
Hawaii:	Mauna Loa	81.07	411.15	50.34	5.47	4.26	17.61	29.76	27.81
P.R:	San Juan	89.45	132.39	57.21	6.91	[b] 2.68	9.93	18.00	12.58
Panama:	Balboa	15.43	15.41	9.82	5.00	[b] 2.40	11.11	13.23	7.21
Ecuador:	Guayaquil	NA	10.51	38.54	4.97	26.29	15.18	234.01	129.13
Peru:	Lima	[b] 5.51	5.91	702.18	141.18	87.53	1,114.83	700.68	330.10
Bolivia:	Chacaltaya	[b] 3.52	47.03	408.73	556.39	1,255.17	2,502.11	1,504.35	408.42
Chile:	Antofagasta	[b] 1.24	NA	543.05	95.97	7.73	18.28	287.88	127.22
	Portillo	42.47	[b] 26.59	1,451.43	361.26	NA	NA	NA	974.24
	Santiago	NA	NA	403.08	154.29	14.99	[b] 2.43	345.14	180.67
	Puerto Montt	NA	NA	41.10	51.82	11.74	42.98	156.39	55.81
	Punta Arenas	NA	NA	5.92	10.52	7.74	22.34	30.62	28.46

[a] No analyses were reported for January through April 1966.
Errors are less than 20 percent except:
[b] Counting error is 20–100 percent.
[c] Counting error is greater than 100 percent.
NA, no analysis.

Table 6. Cadmium-109 concentrations in surface air, January–December 1966

Site		Concentration (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	NA	NA	71.66	[a] 72.39	[a] 70.53	NA	NA	NA	[a] 21.55	NA	NA	[b]
Ocean station:	Bravo	NA	NA	[a] 50.92	[a] 27.09	[a] 15.83	[a] 40.23	NA	NA	[a] 26.96	[a] 20.60	[b]	[a] 54.71
	Charlie	NA	1,301.17	[a] 21.05	[a] 61.05	[a] 12.29	37.99	NA	[a] 26.75	[a] 52.01	NA	NA	NA
Ontario:	Moosonee	[a] 16.54	NA	[a] 63.10	[a] 54.59	[a] 35.88	NA	[a] 49.17	NA	NA	NA	NA	NA
Wash:	Seattle	[a] 37.25	NA	[a] 56.96	NA	[a] 40.91	98.09	NA	[a] 106.75	NA	[a] 70.37	NA	[a] 52.47
Ocean station:	Delta	NA	NA	[a] 56.91	NA	[a] 58.15	NA	[a] 11.61	NA	[a] 20.98	[a] 37.50	NA	[a] 37.80
N.J:	Westwood	[b]	[b]	[b]	[b]	73.46	57.58	[a] 99.23	58.19	[a] 23.85	NA	[a] 35.71	NA
N.Y:	New York City	45.15	NA	93.63	42.20	106.85	103.48	63.50	73.46	41.51	762.20	175.77	9.24
Va:	Sterling	NA	130.47	96.86	[a] 74.59	[a] 51.07	NA	179.85	[a] 28.75	NA	NA	NA	[a] 70.36
Ocean station:	Echo	NA	NA	90.91	[a] 2.69	[a] 43.95	[a] 9.92	NA	NA	[a] 125.96	NA	NA	[a] 49.19
Fla:	Miami	[a] 57.04	NA	[a] 56.94	[a] 99.46	[a] 50.12	[a] 77.22	NA	NA	NA	[a] 73.30	[a] 69.62	[a] 73.51
Bahamas:	Bimini	NA	NA	NA	NA	NA	NA	[a] 271.87	294.57	[a] 40.94	NA	NA	[a] 62.77
Hawaii:	Mauna Loa	[a] 46.74	[a] 45.06	139.25	[a] 244.10	[a] 152.14	[a] 27.60	NA	[a] 98.26	NA	NA	NA	[b]
P.R:	San Juan	[a] 22.38	NA	[a] 329.06	NA	[a] 53.48	[a] 20.93	NA	[a] 46.38	NA	NA	[b]	[a] 75.36
Panama:	Balboa	[a] 16.42	[a] 73.04	[a] 53.81	NA	[a] 25.54	NA	518.04	NA	NA	[a] 68.18	NA	[a] 97.28
Ecuador:	Guayaquil	NA	NA	[a] 140.67	NA	NA	NA	[a] 59.64	[a] 33.41	NA	NA	[b]	NA
Peru:	Lima	[a] 88.28	NA	200.50	NA	[a] 40.49	NA	NA	NA	[a] 44.17	NA	NA	[a] 74.74
Bolivia:	Chacaltaya	[a] 42.15	NA	[a] 68.64	[a] 234.86	NA	NA	[a] 76.98	[a] 59.02	[a] 102.41	[a] 345.99	[b]	[a] 233.68
Chile:	Antofagasta	[a] 74.84	[a] 34.55	[a] 124.44	[a] 112.26	NA	NA	[a] 44.37	NA	[a] 43.69	[b]	NA	[b]
	Portillo	NA	NA	NA	NA	[a] 148.45	NA	[a] 143.43	246.60	NA	NA	NA	[a] 322.73
	Santiago	NA	NA	[a] 247.55	NA	[a] 19.97	[a] 146.45	[a] 36.92	[a] 35.89	[a] 38.81	NA	NA	[a] 78.57
	Puerto Montt	[a] 57.44	[a] 38.87	[a] 33.64	[a] 34.12	[a] 19.30	NA	NA	[a] 42.90	NA	[a] 230.26	NA	NA
	Punta Arenas	NA	NA	[a] 73.93	[a] 28.32	[a] 39.91	NA	148.95	NA	[a] 48.95	NA	NA	[a] 158.24

Errors are less than 20 percent except:
[a] Counting error is 20–100 percent.
[b] Counting error is greater than 100 percent.
NA, no analysis.

Results

The updated radioactivity concentrations in surface air during 1966 are presented in tables 1 through 11. The sites are listed according to latitude beginning with the most northern site at Thule, Greenland. The results of the blank and standard analyses are reported in tables 12 and 13.

The concentrations are reported at the midpoint of the collection month for the plutonium isotopes and the fission products and on the following dates for the induced nuclides:

Table 7. Cesium-137 concentrations in surface air, January-December 1966[a]

Site		Concentration (dpm/1,000 standard m³ at midmonth)			
		January	February	March	April
Greenland:	Thule	NA	34.08	38.41	34.32
Ocean station:	Bravo	NA	11.20	16.50	25.37
	Charlie	NA	7.13	18.42	17.60
Ontario:	Moosonee	13.99	15.45	22.27	16.06
Ocean station:	Delta	NA	15.91	21.64	15.51
N.J:	Westwood	NA	NA	NA	24.90
N.Y:	New York City	18.27	13.98	26.39	24.16
Va:	Sterling	14.12	14.89	27.35	15.32
Ocean station:	Echo	NA	24.31	29.75	22.65
Fla:	Miami	22.09	20.05	40.47	40.00
Hawaii:	Mauna Loa	35.04	22.25	52.22	37.58
P.R:	San Juan	9.82	20.52	26.32	16.36
Panama:	Balboa	9.10	13.36	16.75	12.84
Ecuador:	Guayaquil	3.46	3.41	2.56	1.97
Peru:	Lima	12.54	11.26	6.82	4.90
Bolivia:	Chacaltaya	8.31	3.21	4.58	4.17
Chile:	Antofagasta	7.99	8.74	17.96	5.14
	Santiago	18.25	16.91	9.02	5.88
	Puerto Montt	8.98	7.34	4.87	4.02
	Punta Arenas	5.29	3.74	4.76	2.91

[a] No analyses were reported for May through December.
NA, no analysis.

Manganese-54 and iron-55 : October 15, 1961
Cadmium-109 : July 9, 1962

One standard deviation of the counting error for these data is always less than ±20 percent and usually less than ±10 percent unless otherwise indicated.

Data reliability

The quality of the radiochemical analysis is monitored through the use of various "knowns" submitted to the contractor each month along with regular samples. Basically, there are three kinds of quality control samples: blanks, standards, and duplicates.

A blank is prepared by sprinkling a small amount of pre-1945 soil (10 mg) onto an unexposed microsorban filter. Then, carbon soot from burning napthanlene is filtered onto the microsorban paper for a few moments under laboratory conditions. This procedure produces blanks which are very similar in appearance, and in some re-

Table 8. Cerium-141 concentrations in surface air, January–December 1966[a]

Site		Concentration (dpm/1,000 standard m³ at midmonth)							
		May	June	July	August	September	October	November	December
Greenland:	Thule	[b] 555.56	19.19	[b] 32.85	NA	147.51	NA	[b] 48.73	NA
Ocean station:	Bravo	261.76	17.97	32.10	81.88	[b] 41.54	NA	80.39	[c]
	Charlie	NA	[b] 33.62	NA	NA	[b] 101.93	NA	[b] 94.37	NA
Ontario:	Moosonee	NA	58.75	NA	NA	[b] 94.40	[b] 19.70	[b] 46.01	[c]
Wash:	Seattle	[b] 19.90	25.41	[b] 26.25	NA	[b] 99.25	[b] 36.79	NA	NA
Ocean station:	Delta	NA	39.05	[b] 28.24	[b] 27.52	[b] 69.72	NA	[b] 88.23	[b] 221.65
N.Y:	New York City	242.58	68.94	47.31	49.78	[b] 77.81	22.77	NA	[b] 180.00
Va:	Sterling	[b] 32.70	[b] 97.40	100.50	[a] 30.71	NA	[a] 24.70	[b] 129.15	NA
Ocean station:	Echo	[b] 26.53	[b] 37.97	NA	72.37	[b] 44.09	NA	NA	[b] 94.90
Fla:	Miami	240.00	152.41	58.33	[b] 59.95	[b] 87.15	[b] 12.26	NA	NA
Bahamas:	Bimini	NA	NA	92.19	[b] 69.38	361.02	NA	[b] 155.59	NA
Hawaii:	Mauna Loa	263.93	585.37	127.74	47.39	NA	NA	NA	NA
P.R:	San Juan	115.59	135.73	77.75	NA	NA	NA	NA	NA
Panama:	Balboa	[b] 30.81	15.08	[b] 16.86	36.93	[b] 47.51	NA	NA	[b] 391.16
Ecuador:	Guayaquil	NA	[b] 14.91	539.06	[b] 16.57	[b] 71.01	[b] 394.33	NA	[b] 972.97
Peru:	Lima	[b] 2.98	15.40	113.56	141.18	NA	[b] 1,830.14	NA	[b] 1,363.32
Bolivia	Chacaltaya	12.43	79.24	650.79	[b] 620.30	[b] 1,120.69	[b] 2,050.63	NA	NA
Chile:	Antofagasta	NA	NA	792.49	185.46	NA	2,187.94	NA	NA
	Portillo	[b] 27.63	16.78	1,571.43	[b] 108.90	NA	NA	NA	NA
	Santiago	NA	[b] 3.64	584.62	199.39	[b] 199.22	NA	NA	[c]
	Puerto Montt	NA	NA	10.88	139.60	[b] 191.55	NA	[b] 977.44	NA
	Punta Arenas	NA	[b] 3.44	9.70	28.51	[b] 78.32	NA	[b] 217.98	NA

[a] No analyses were reported for January through April 1966.
Errors are less than 20 percent except:
[b] Counting error is 20–100 percent.
[c] Counting error is greater than 100 percent.
NA, no analysis.

XUM

Table 9. Cerium-144 concentrations in surface air, January–December 1966

Site		Concentration (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	NA	50.00	42.39	42.36	28.99	18.97	9.85	8.52	6.30	6.29	9.61	10.39
Ocean station:	Bravo	NA	17.41	21.61	25.12	8.07	10.90	5.02	6.70	2.85	.91	4.56	3.77
	Charlie	NA	9.53	23.37	27.37	13.77	8.29	5.35	6.15	2.77	2.12	8.59	3.78
Ontario:	Moosonee	17.11	21.10	24.02	17.57	22.50	20.42	23.14	8.56	5.39	3.82	11.46	5.10
Wash:	Seattle	13.67	16.61	23.52	23.59	24.65	14.40	11.69	7.45	4.47	3.31	1.25	3.98
Ocean station:	Delta	NA	21.10	27.45	20.63	23.48	18.79	13.99	4.62	5.02	2.44	11.26	3.73
N.J:	Westwood	22.13	22.41	31.30	25.75	48.72	52.25	28.79	10.71	5.96	NA	4.20	NA
N.Y:	New York City	19.86	15.67	31.96	25.86	45.52	46.21	38.06	14.44	6.29	6.44	46.58	11.25
Va:	Sterling	18.26	20.76	28.25	17.41	36.04	45.45	28.36	11.82	6.10	5.37	14.72	7.68
Ocean station:	Echo	NA	34.08	34.50	30.27	35.66	12.89	NA	7.16	5.12	2.75	8.43	2.69
Fla:	Miami	30.99	29.20	47.29	45.95	49.41	38.48	12.65	7.25	2.38	5.05	38.61	11.61
Bahamas:	Bimini	NA	NA	NA	NA	NA	NA	24.06	13.10	5.39	11.29	60.06	16.55
Hawaii:	Mauna Loa	40.94	35.10	56.66	39.75	114.64	113.59	26.99	7.46	5.00	3.47	13.83	16.25
P.R:	San Juan	11.64	26.50	24.79	18.72	24.22	35.73	15.94	8.91	3.79	3.13	7.66	6.10
Panama:	Balboa	11.18	20.64	17.64	15.86	6.68	2.28	3.32	2.43	.80	2.51	5.57	3.91
Ecuador:	Guayaquil	3.44	4.03	2.04	1.85	1.55	[a] 3.99	39.84	6.18	5.31	51.80	36.05	49.25
Peru:	Lima	12.99	12.60	7.69	5.00	3.39	5.73	101.21	21.67	22.17	255.02	209.86	115.22
Bolivia:	Chacaltaya	5.74	4.94	4.49	4.27	3.92	16.69	583.33	104.14	1,437.93	414.35	361.74	142.11
Chile:	Antofagasta	11.76	9.45	4.99	4.45	3.57	5.51	88.74	14.94	17.48	230.86	106.67	53.52
	Portillo	NA	NA	NA	NA	15.46	11.16	210.86	95.81	NA	NA	NA	510.61
	Santiago	12.71	14.07	8.25	5.53	4.16	3.64	670.77	29.57	15.44	72.79	107.78	88.66
	Puerto Montt	8.00	8.62	5.20	7.36	2.46	3.36	2.75	11.06	7.42	8.90	46.02	18.72
	Punta Arenas	4.66	4.14	4.17	2.66	1.69	1.44	2.14	3.34	2.73	4.83	10.11	7.55

Errors are less than 20 percent except:
[a] Counting error is 20–100 percent.
NA, no analysis.

Table 10. Plutonium-238 concentrations in surface air, January–December 1966

Site		Concentration (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	NA	[a] 0.79	0.80	[a] 1.92	[a] 0.96	1.30	[a] 0.44	[a] 9.26	2.79	[a] 2.22	[b]	[a] 0.30
Ocean station:	Bravo	NA	NA	NA	2.61	.80	[a] .70	1.50	NA	1.10	[a] 2.52	[a] 2.27	NA
	Charlie	NA	NA	.80	4.29	.90	[a] 1.00	[a] .40	[a] 1.30	[a] .70	[a] 1.22	[b]	NA
Ontario:	Moosonee	NA	[a] 1.72	[a] .48	NA	[a] .82	[a] .64	[a] 1.49	[a] 2.80	2.45	[a] 1.44	[a] .93	[a] .81
Wash:	Seattle	[a] 1.16	NA	[a] .54	[a] 2.96	[a] 1.18	NA	5.07	[a] .77	3.04	[a] 1.85	[b]	1.54
Ocean station:	Delta	NA	[a] 1.10	[a] .80	[a] 1.30	[a] 1.00	3.51	[a] .51	[a] .70	[a] .50	[a] 1.83	[a] 1.87	NA
N.J:	Westwood	[a] .74	[a] .42	.75	7.55	1.73	2.05	22.51	5.47	3.56	2.96	[a] 1.15	NA
N.Y:	New York City	1.36	1.79	.57	5.07	3.71	8.86	2.97	2.33	2.30	2.90	4.95	3.72
Va:	Sterling	NA	[a] .41	[a] .52	NA	91.17	1.87	2.69	[a] 4.08	5.07	[a] 1.73	NA	[a] 1.62
Ocean station:	Echo	NA	NA	[a] .80	[a] 3.21	2.21	.70	NA	[a] 4.81	3.39	[a] 2.81	[a] 1.95	NA
Fla:	Miami	[a] 1.18	NA	1.40	[a] 1.88	[a] 2.28	[a] 1.54	[a] 1.33	NA	1.78	[a] 1.17	[a] 1.80	[a] .83
Bahamas:	Bimini	NA	NA	NA	NA	NA	NA	[a] 1.86	[a] 5.12	NA	[a] 4.24	[b]	NA
Hawaii:	Mauna Loa	[a] .66	[a] 1.95	1.62	5.00	[a] 2.44	[a] 1.94	[a] 1.79	[a] 5.57	NA	[a] 1.69	NA	14.62
P.R:	San Juan	[a] 2.44	[a] .79	[a] .38	NA	[a] 1.98	[a] .78	[a] .67	[a] 3.00	[a] 4.20	[a] 3.65	NA	[a] 1.46
Panama	Balboa	[a] .78	NA	[a] .34	NA	NA	NA	NA	NA	1.23	[a] 2.37	[a] 3.16	[a] 5.14
Ecuador:	Guayaquil	NA	NA	[a] .22	NA	[a] .22	[a] 1.68	NA	[a] 1.94	4.45	[a] 6.24	[b]	7.24
Peru:	Lima	NA	NA	9.42	[a] .44	[a] 1.52	[a] 1.31	[a] 4.94	[a] 5.17	13.58	24.40	[b]	16.33
Bolivia:	Chacaltaya	[a] .40	NA	[a] .40	[a] 6.10	[a] 2.62	9.03	13.65	[a] 9.81	91.03	23.21	[b]	[a] 16.84
Chile:	Antofagasta	[a] .22	[a] .87	[a] .33	[a] 1.51	[a] 1.37	[a] 2.03	19.25	[a] 5.30	[a] 13.53	24.83	[b]	8.17
	Portillo	NA	NA	NA	NA	[a] 9.55	[a] 7.39	65.14	[a] 37.07	NA	NA	NA	95.91
	Santiago	[a] 1.41	[a] .47	[a] 1.07	[a] .95	NA	4.30	2.43	1.51	15.21	[a] 4.42	[a] 3.50	11.22
	Puerto Montt	[a] .42	[a] .94	NA	[a] 2.28	[a] .62	2.46	[a] 1.54	[a] 11.25	34.93	3.40	[a] 5.49	[a] 2.38
	Punta Arenas	NA	NA	NA	[a] 1.57	[a] .41	[a] 1.63	NA	[a] 3.26	4.59	3.66	[b]	[b]

Errors are less than 20 percent except:
[a] Counting error is 20–100 percent.
[b] Counting error is greater than 100 percent.
NA, no analysis.

Table 11. Plutonium-239 concentrations in surface air, January–December 1966

Site		Concentration (dpm/1,000 standard m³ at midmonth)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Greenland:	Thule	NA	33.44	37.47	47.18	35.99	19.67	8.08	[a] 5.48	29.83	3.69	[a] 3.32	4.40
Ocean station:	Bravo	NA	9.20	19.41	45.32	15.09	10.80	3.99	[a] 3.20	9.30	2.43	6.47	2.61
	Charlie	NA	7.81	NA	30.74	16.87	6.79	3.89	[a] 6.80	2.50	3.88	[a] 6.82	2.04
Ontario:	Moosonee	[a] 7.85	13.37	26.64	30.05	23.38	20.00	16.20	[a] 5.18	18.50	26.79	3.88	3.95
Wash:	Seattle	7.90	11.86	24.36	36.65	25.18	12.87	12.59	1.76	20.08	5.88	11.83	3.95
Ocean station:	Delta	NA	[a] 12.20	33.27	25.05	25.88	[a] 14.10	6.70	2.70	10.80	27.98	[a] 2.75	[a] 1.72
N.J:	Westwood	29.19	17.15	31.04	[a] 48.50	48.02	71.35	78.64	12.45	9.51	5.87	5.96	NA
N.Y	New York City	16.48	5.95	34.13	46.64	87.15	33.21	27.45	18.52	12.20	17.42	12.27	15.72
Va:	Sterling	13.62	10.12	30.04	27.76	41.53	37.66	24.23	11.15	46.75	8.49	8.19	5.80
Ocean station:	Echo	NA	13.89	32.02	41.26	39.80	5.20	NA	15.10	7.60	6.02	[a] 7.19	[a] 4.85
Fla:	Miami	27.70	NA	50.12	61.08	16.82	17.44	8.11	[a] 1.77	11.54	[a] 5.75	5.85	6.99
Bahamas:	Bimini	NA	NA	NA	NA	NA	NA	13.44	12.36	188.58	13.38	46.33	8.18
Hawaii:	Mauna Loa	28.48	24.19	58.36	50.93	44.29	38.33	16.92	[a] 11.15	NA	4.47	6.65	14.81
P.R:	San Juan	9.74	24.80	29.74	24.49	25.42	14.37	7.75	7.97	84.47	7.58	2.71	6.79
Panama:	Balboa	9.16	9.30	17.87	[a] 1.12	7.03	[a] .78	[a] 2.58	[a] 3.69	14.46	3.79	5.84	7.14
Ecuador:	Guayaquil	[a] 2.34	4.79	2.97	3.02	1.65	[a] 1.80	30.21	4.62	6.83	[a] 11.06	[a] 4.13	8.41
Peru:	Lima	6.98	15.84	[a] 1.22	19.33	5.32	3.17	43.34	5.61	16.78	NA	[a] 3.10	19.55
Bolivia:	Chacaltaya	5.86	[a] 7.92	6.06	12.06	3.22	8.43	61.90	[a] 26.28	157.93	43.88	[a] 12.35	32.21
Chile:	Antofagasta	10.97	9.27	5.19	7.45	5.13	4.83	44.37	9.44	60.51	29.47	[a] 17.88	11.28
	Portillo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Santiago	6.95	9.84	8.10	9.23	NA	5.12	13.88	10.80	13.63	10.74	16.07	17.52
	Puerto Montt	6.98	11.74	5.27	6.31	2.66	3.59	[a] 4.73	9.08	25.34	6.58	13.01	7.62
	Punta Arenas	[a] 4.63	4.36	4.79	4.29	2.03	2.03	2.96	[a] 8.74	17.55	3.20	[a] 8.43	[a] 4.87

Errors are less than 20 percent except:
[a] Counting error is 20–100 percent.
NA, no analysis.

Table 12. Quality control results on blank samples—1966 (Average values in dpm per sample)

Month (1966)	Manganese-54	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cadmium-109	Cesium-137	Cerium-141	Cerium-144	Plutonium-238	Plutonium-239
January	288	[a] 47		[b] 1.0		[b] 16	[b] 1.1		0	[b] 0.1	[b] 0.1
February	[a] 150	[a] 47		[b] 1.0		[a] 20	[b] 2.0		[b] 1.3	[b] .1	[b] .3
March	475	[a] 123		[b] .2		0	44.5		0	0	[b] .1
April	0	207		[b] .6		0	[b] 3.3		[b] 3	[b] .1	0
May		0	[b] 8	[b] 0	0	0		0	0	[b] .3	[b] .1
June		[a] 104	0	0	0	0		[a] 56	[b] 4	[b] .1	[b] 1.0
July		139	0	0	310	0		[a] 100	[b] 4	[b] .1	[b] 1.0
August		0	0	0	102	[b] 14		0	0	0	0
September		0	[b] 2	[b] .4	0	0		584	0	[b] .8	[a] 13.0
October		0	0	0	[b] 47	[b] 27		4,000	0	[b] 1.3	[b] 3.7
November		0	[a] 33	0	[b] 12	[a] 54		[b] 0	[b] 2	[b] .3	[b] .2
December		0	0	[b] .7	[b] 0	[b] 0		[b] 0	[b] 1	0	[b] .2

One standard deviation of counting error is ±20 percent except for:
[a] = ±20 percent to ±100 percent.
[b] = greater than ±100 percent.

Table 13. Quality control results on standard samples—1966 (Average values in percent deviation)

Month (1966)	Manganese-54	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cadmium-109	Cesium-137	Cerium-141	Cerium-144	Plutonium-238	Plutonium-239
January	−2	−17		−2		−28	−1		+15		−8
February	+10	−18		−10		−86	0		+38		−46
March	−50	+13		−6		+4	−34		−14		−10
April	−2	+5		−30		−75	−40		−14		+16
May		−10		−4		−2			−1		+10
June		−58	−18	+12	+19	−17		−1	−10		+10
July		+43	−24	−11	+23	−26		−72	+20		−58
August		+2	−32	+10	+29	−19		+700	−24	−23	+30
September		−36	−40	−9	+25	−40		+250	−9	−36	+870
October		−1	−24	−8	+100	−34		+1,000	−100	−24	+2
November		+28	−15	+2	−8	−14		+10	+16	+200	+62
December		+31	+49	−78	−9	−22		+69	+109	−93	−59

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Table 14. Quality control results on duplicate samples—1966
(Values are ± precent standard deviation)

Month (1966)	Manganese-54	Iron-55	Strontium-89	Strontium-90	Zirconium-95	Cadmium-109	Cesium-137	Cerium-141	Cerium-144	Plutonium-238	Plutonium-239
January	9	4		9		176	8		2	70	5
February	10	6		4		—	1		2	45	14
March	5	13		5		64	2		1	42	4
April	3	10		1		—	3		2	—	32
May		11	2	8	24	54		54	3	96	16
June		18	28	2	31	27		17	2	90	38
July		3	36	1	11	5		38	14	33	76
August		176	5	38	27	—		2	6	15	20
September		46	—	10	8	74		—	58	76	23
October		37	16	9	45	—		37	16	58	9
November		11	43	3	61	40		—	76	9	36
December		23	—	32	13	—		21	2	61	74

spects, composition to the routine filters collected by this program. When the blanks are coded, as are all the filters submitted to radiochemistry, they are not readily distinguishable from routine samples. Table 12 lists the results of analyses of blanks in 1966. The table summarizes the average dpm reported from blanks sent out each month. It is evident from a review of these data that the contamination problem has been quite variable, and consequently low level concentrations in the real samples must be considered with care.

A standard is prepared at HASL onto a blank sample. A few drops of wetting agent is applied to the blank prior to the addition of the standard to permit permeation of the solution between the polyethylene fibers of the microsorban filter. Table 13 presents the results of these analyses for each nuclide in 1966. The values are average percent deviations of the reported analyses from the known. Again the results are seen to be extremely variable and generally nonsystematic.

Duplicate collections are made monthly at the New York site. These samples are composited and split before analyses thereby providing a measure of the reproducibility of the radiochemical procedures. The results of these tests are shown as the percent standard deviation from the mean, in table 14.

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Data for 1967–1969 available in HASL-227

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1965	January 1967

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Radionuclides in Alaskan Caribou and Reindeer, May-December 1969

Bureau of Radiological Health
U.S. Public Health Service

Under a cooperative agreement between the Alaskan Department of Health and Welfare, the Alaskan Department of Fish and Game, and the U.S. Public Health Service, a program of caribou and reindeer sampling and analysis was undertaken in 1963 to aid in the assessment of radionuclide intake of Alaskan residents. This joint sampling activity was continued based on results of a limited sampling effort conducted by these groups in 1962.

Through the second quarter of 1964, the sampling was confined to the three principal caribou herds and one privately-owned reindeer herd. This program was expanded in September 1964, when the sampling of additional privately-owned and government-owned reindeer herds was begun

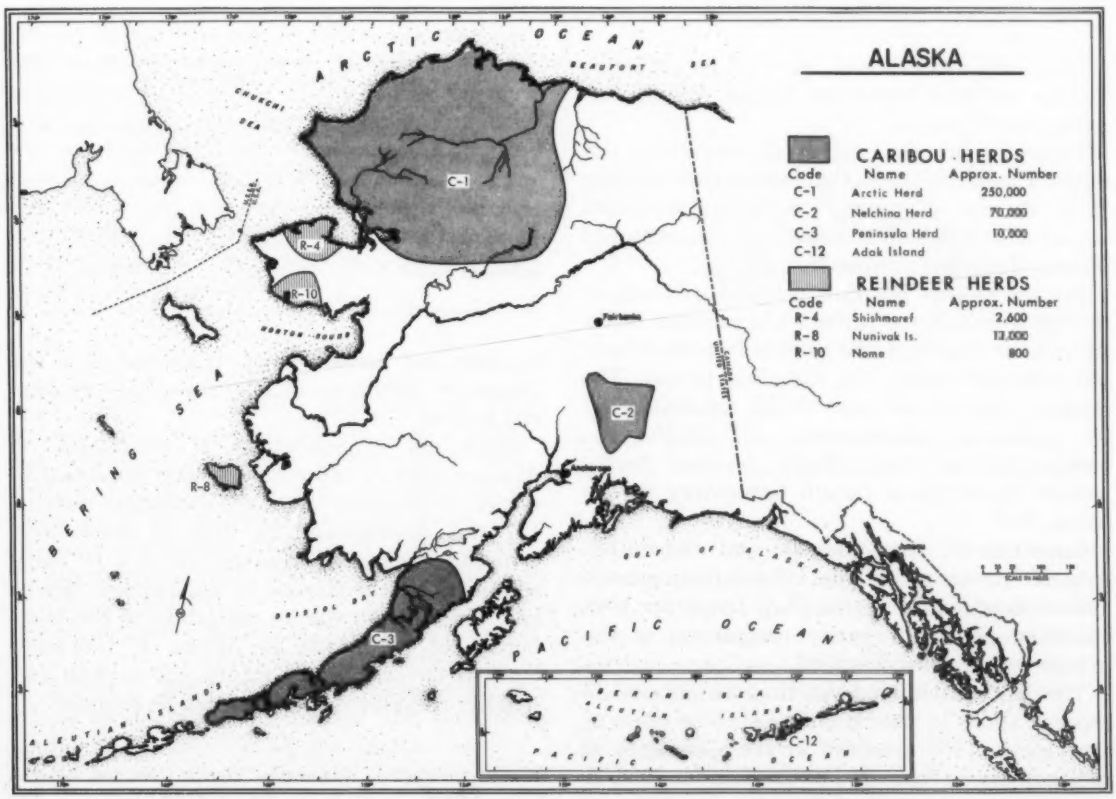

Figure 1. Locations of caribou and reindeer herds sampled in Alaska

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Table 1. Radionuclide concentration in muscle of Alaska caribou and reindeer, May–December 1969

Herd and sampling locations[a]	Collection date (1969)	Sex	Age (years)	Concentration (pCi/kg wet weight)		Cesium-137 concentration (nCi/kg wet weight)
				^{89}Sr	^{90}Sr	
Arctic caribou herd: Anaktuvuk Pass, C-1	10/10	F				2.1
	10/10	M				4.7
	10/10	M				3.2
	10/11	F				3.4
	10/11	M				4.1
Nelchina caribou herd: Dickey Lake, C-2	10/9	M				2.6
	10/10	M				5.5
	10/10	F				4.0
	10/11	F				4.4
	10/11	F				4.6
Peninsula caribou herd: King Salmon, C-3	9/29	F				2.6
	9/29	M				6.8
	9/30	F				1.5
	9/30	F				2.0
	10/9	F				5.1
Shishmaref reindeer herd: Seward Peninsula, R-4	5/6	F		[b,c] 0	[b] 8	11
	5/6	M				15
	5/6	F				14
	5/6	M				15
	5/6	M				12
	12/14	F	2	0	5	12
	12/14	M	2	0	6	12
	12/14	M	2	0	7	11
	12/14	M	2	0	<4	11
	12/14	F	.7	0	6	15
Adak caribou herd: Adak Island:	8/14	M				2.4
	8/14	F				1.6
	8/14	F				2.1
	8/13	F				2.1

[a] Sampling locations are shown in figure 1.
[b] Composite of individual samples taken within herd.
[c] All results ≤5 pCi/kg wet weight are reported as 0.

through the assistance of the Fish and Wildlife Service and the Bureau of Indian Affairs, Department of Interior.

Figure 1 shows the locations of the caribou and reindeer herds in Alaska that were sampled during 1969. Because of nuclear testing at Amchitka Island, a caribou herd at Adak Island was sampled instead of reindeer samples from Nome.

For the present program, samples are taken in the fall from selected caribou and reindeer herds. Samples of muscle of five animals from each herd are collected during the sampling period. The samples are analyzed individually for cesium-137 by gamma-ray spectroscopy. All samples are analyzed at the Public Health Service's Southwestern Radiological Health Laboratory in Las Vegas, Nev.

Strontium-89, strontium-90, and cesium-137 data are presented in table 1 for caribou muscle and reindeer muscle for the May–December 1969 collection period. A yearly comparison of the muscle data is shown in table 2.

The data in table 2 indicate that the cesium-137 concentrations in muscle during similiar times of the year in 1969 remained at the same level of radioactivity as compared to the data for 1968. A summary of the strontium-90.and cesium-137 concentrations in foodstuffs in Alaska (including reindeer and caribou meat) is contained in the December 1966 issue of *Radiological Health Data and Reports.*

Table 2. Cesium-137 concentrations in caribou and reindeer muscle, 1968 and 1969

Herd	Average cesium-137 concentration (nCi/kg wet weight)	
	1968	1969
Arctic caribou	5 (October)	4 (October)
Nelchina caribou	2 (September)	4 (October)
Peninsula caribou	5 (October)	4 (September)
Shishmaref reindeer	15 (April)	13 (May)
	11 (November)	12 (December)

Since the concentrations of cesium-137 in Alaskan caribou and reindeer have continued to remain at the same levels, the analysis of cesium-137 was discontinued in 1970. A whole-body counting project of Alaskan natives is being continued by the Bureau of Radiological Health and will still provide an indication of the body burden of the people in Alaska. If the body burdens increase in the future, the caribou and reindeer surveillance program can be resumed.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
March–May 1968	December 1968
September–November 1968	June 1969

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Knolls Atomic Power Laboratory and the Portsmouth Area Gaseous Diffusion Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Knolls Atomic Power Laboratory[2] January–December 1968

General Electric Company
Schenectady, N. Y.

The principal function of the Knolls Atomic Power Laboratory (KAPL), operated by the General Electric Company for the Atomic Energy Commission, is to support the Naval Reactors Program of the AEC in the development of atomic power for naval propulsion. This includes design, construction, and prototype operation of nuclear power reactors. The Knolls Atomic Power Laboratory consists of two sites, the Knolls site and the Kesselring site (figure 1).

Knolls site

The Knolls site occupies approximately 170 acres on which are located administrative buildings; chemistry, physics, metallurgical, engineering, and radioactive materials laboratories; critical assembly buildings; machine shops, decontamination facilities; radioactive waste storage and processing facilities; and nuclear fuel storage and assembly buildings.

The Knolls site releases small amounts of radioactive materials both to the atmosphere and to the Mohawk River. Prior to release, exhaust air and liquid waste are treated and carefully monitored. In addition to the inplant control monitoring, an environmental monitoring program is conducted both on- and offsite at the Knolls site to: (1) audit the operational control of radioactive waste release to the environment, and (2) to ascertain compliance with the radioactivity standards established by the AEC.

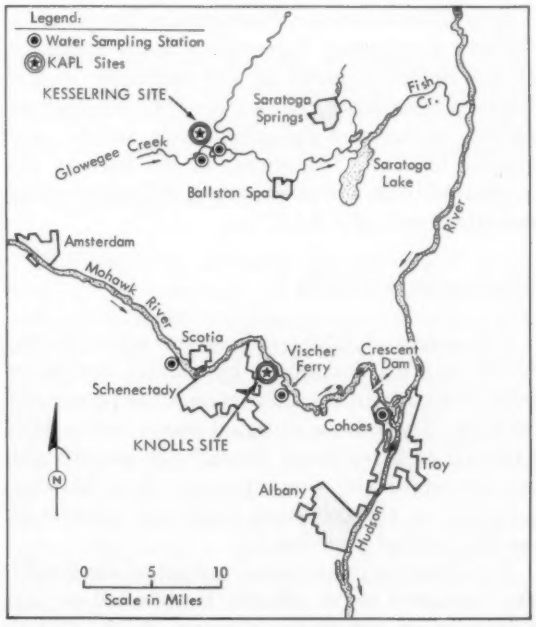

Figure 1. Environmental monitoring locations, KAPL

Air monitoring

Environmental airborne radioactivity is measured at two locations at the Knolls site and at

[2] Summarized from "Knolls Atomic Power Laboratory, Knolls Site and Kesselring Site: Annual Environmental Monitoring Report, January–December 1968."

one location at the General Electric Company Research and Development Center, approximately 1 mile west of the Knolls site.

The results of the beta-gamma radioactivity analyses of environmental air at the Knolls and offsite sampling locations show average concentrations of 71 fCi/m³ and 95 fCi/m³, respectively. The results were all less than the most restrictive permissible airborne concentrations for beta-emitting radionuclides given in AEC Manual Chapter 0524 (strontium-90, 30 pCi/m³). Most of the environmental air results were less than 50 fCi/m³, the value considered valid at the 90-percent confidence level with an error of 30 percent. The maximum concentration (250 fCi/m³) was detected during the second week of May 1968.

In addition to the environmental airborne radioactivity monitoring, surveys are made routinely of the radiation levels at the perimeter of the Knolls site facilities. The surveys of 1968 showed normal background radiation levels for the geographic location. The results of the surveys extrapolated to an annual exposure, indicate average radiation levels of <0.1 R/a.

Liquid waste monitoring

All sources of liquid radioactive waste at the Knolls site are connected by control drains to collection tanks in the radioactive waste processing building. The release of liquid waste to the Mohawk River is regulated through the control and monitoring of the concentration of radioactive materials in the collection tanks and control of the discharge of the effluent.

A continuous proportional sample of the Knolls site combined sewer effluent is collected at the point of discharge to the Mohawk River. Radiochemical analyses of weekly composite samples show that strontium-90 is the principal component to be considered in control.

A total of 56.7 millicuries of beta and 6.2 millicuries of alpha radioactivity was discharged to the Mohawk River during 1968. The average annual concentration of strontium-90, which comprised 32.5 percent of the total beta radioactivity in the effluent, was 12 pCi/ml or 4 percent of its environmental standard as given in AEC Manual Chapter 0524. The average annual gross alpha concentration was less than 1 percent of the AEC standard for plutonium-239 (5 nCi/liter).

Water monitoring

Mohawk River water is sampled continuously at the General Electric Company powerhouse, 8 miles upstream from the Knolls site; at the Vischer Ferry powerhouse, 1.7 miles downstream; and at the Cohoes, N.Y., pumping station, 13 miles downstream. A continuous sample of Cohoes municipal water, which is derived from river water, is also collected at the Cohoes pumping station. The weekly water samples are composited and analyzed for radioactivity on a monthly basis. Average quarterly beta-gamma concentrations are given in table 1.

Table 1. Radioactivity in Mohawk River water near the Knolls site, 1968

Sampling period (1968)	Beta-gamma radioactivity (pCi/liter)			
	G.E. Powerhouse (upstream)	Vischer Ferry (downstream)	Cohoes raw water (downstream)	Municipal water
January–March	9	1	5	2
April–June	6	2	3	3
July–September	5	6	7	8
October–December	6	6	5	3

Sediment monitoring

The Mohawk River monitoring program at the Knolls site consists of a quarterly collection and analysis of Mohawk River sediment. Samples are collected at 15 specific locations and all are analyzed for gamma (cesium-137 equivalent), gross beta (cesium-137 equivalent) and alpha (plutonium-239 equivalent) radioactivity content; in addition, three of the samples are analyzed for strontium-90 content. The Knolls site radioactive liquid waste disposal program did not significantly influence the radioactivity levels of the Mohawk river sediment. In three of the four quarters, the sample location yielding the highest results was location No. 4. This location is directly downstream from the Knolls site sewer outfall to the river. General concentrations rapidly diminished with increased distances from the sewer outfall. The radioactivity concentrations in Mohawk River sediment samples are given in table 2.

Table 2. Radioactivity concentrations in Mohawk River sediment, KAPL, 1968[a]

1968	Number of samples	Total radioactivity (pCi/g)				Strontium–90 (pCi/g)		Cesium–137 (pCi/g)	
		Alpha		Beta					
		Average	Range	Average	Range	Average	Range	Average	Range
January–March	15	0.70	0.2–1.3	14	7.9–42	0.21	0.1–0.4	4.3	0.4– 52.9
April–June	15	.96	.3–4.5	12	5.0–21	.90	.6–1.1	2.5	.2– 26.9
July–September	15	.66	.3–3.1	18	8.3–87	1.33	.2–3.3	15.5	.8–206
October - December	15	.81	.4–1.8	16	10 –24	.49	.3– .9	5.8	1.4– 21.2

[a] Minimum detectable concentration for a 600 g sample at 90-percent confidence level:
Alpha—0.1 pCi/g
Beta—9.0 pCi/g
Strontium–90—1.1 pCi/g
Cesium–137—0.4 pCi/g
Concentration for 600 g sample detectable at 90-percent confidence level with 30 percent error:
Alpha—0.8 pCi/g
Beta—24 pCi/g
Strontium–90—3.0 pCi/g
Cesium–137—1.5 pCi/g
The variation in the detectable levels is the result of differences in the size of sediment aliquots analyzed; i.e., cesium–137, total sample. Each sediment sample represents a surface area of 230 cm².

Mohawk River fish radioactivity

Specimens of Mohawk River fish are collected annually at the Vischer Ferry Dam at the discharge point of the powerhouse effluent. This location is approximately 9,000 feet downstream from the Knolls site sewage outfall.

Samples of the total body are analyzed for gamma radioactivity (cesium-137 equivalent) and samples of the edible tissues are analyzed for strontium-90 content and alpha radioactivity (plutonium-239 equivalent). The specimens, which were all carp, were collected on October 28, 1968.

There were no detectable concentrations of strontium-90 or alpha radioactivity found in the fish samples [minimum detectable concentrations 0.051 pCi/g (100 g sample) for strontium-90, and 0.068 pCi/g (10 g sample) for alpha radioactivities]. The average cesium-137 concentration, based on analysis of the total fish, was 0.095 pCi/g, which is less than the radioactivity level valid at the 90-percent confidence level with an error of 30 percent.

The above results indicate that Knolls operations had no discernible effect upon the radioactivity levels of Mohawk River fish.

Kesselring site

The Kesselring site, located on approximately 4,000 acres near West Milton, N.Y., is a part of the Knolls Atomic Power Laboratory. Its principal facilities include the Triton (S3G) and Bainbridge (D1G) prototype reactors, equipment service building, fuel service building, and waste treatment facilities. Regular environmental monitoring activities are conducted to verify that laboratory releases of radioactivity to the environment are in compliance with AEC standards.

Air monitoring

Environmental airborne radioactivity is measured at one location at the Kesselring site. Airborne radioactivity is sampled continuously and analyzed on a semiweekly basis. The environmental monitoring station is equipped with a film dosimeter to detect integrated gamma radioactivity levels. The results of the beta-gamma, long-lived radioactivity analyses at the Kesselring site showed an average of 0.12 ± 0.02 pCi/m³. The results were all less than the most restrictive permissible airborne concentration for beta-emitting radionuclides set forth in AEC Manual Chapter 0524.

In addition to the environmental airborne radioactivity monitoring, surveys are made semiannually of the radiation levels at the Kesselring site perimeter. Perimeter surveys performed during the year showed normal background radiation levels for the geographic location. The result of the perimeter survey extrapolated to an annual exposure indicates average perimeter radiation levels of <0.1 R/a.

Radioactive liquid waste disposal

The liquid waste from the Kesselring site is collected, processed, and sampled prior to release to

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the Glowegee Creek. The radioactive waste discharged to the Glowegee Creek in terms of total radioactivity in liquid wastes was 3.7 millicuries for 1968. Radiochemical analyses of these wastes indicated that strontium-89 and strontium-90 concentrations were less than 1 percent of the respective AEC standards for this reporting period. The average result for unidentified radionuclides in the D1G and S3G effluents (19 and 118 pCi/liter) represent less than 1 percent and less than 4 percent, respectively, of the applicable AEC standard (3 nCi/liter).

The average concentrations of beta and gamma radioactivity detected in Glowegee Creek water upstream and downstream from the S3G and D1G liquid-waste outfalls are shown in table 3. All but two Glowegee Creek water analysis results were below 10 pCi/liter which is the measured concentration that may be considered valid at the 90-percent confidence level with a maximum error of 30 percent.

Table 3. Radioactivity in Glowegee Creek water from the Kesselring site operations, KAPL, January–December 1968

Year (1969)	Beta and gamma radioactivity (pCi/liter)	
	Glowegee Creek (upstream)	Glowegee Creek (downstream)
January–March	15.0	<3.2
April–June	10.0	3.5
July–September	5.1	5.1
October–December	<8.0	8.0
Calendar year	<9.5	<5.0

Water monitoring

Samples of the Glowegee Creek water are analyzed for radioactivity once each quarter year at two locations, one is about 150 feet above the point where the S3G effluent enters the creek and the other is about 1,500 feet below the D1G effluent discharge point.

Sediment monitoring

Glowegee Creek sediment radioactivity measurements are analyzed on a monthly basis. Sample locations are the same as those listed for Glowegee Creek water sampling. The sediment analysis results are shown in table 4.

General conclusions

As a result of the environmental monitoring program conducted by the Knolls Atomic Power Laboratory, it is concluded that the operation of the Knolls and Kesselring installations did not adversely affect the radioactivity levels of the local environment. The results of the environmental surveys indicate that the levels of radioactivity detected at all times were within the standards established by the U.S. Atomic Energy Commission in the AEC Manual Chapter 0524, "Radiation Protection Standards."

Recent coverage in *Radiological Health Data and Reports.*

Period	Issue
January–December 1967	February 1969

Table 4. Radioactivity in Glowegee Creek sediment, KAPL, January–December 1968

1968	Location	Number of samples	Gross gamma radioactivity (pCi/g)		Cobalt-60 (pCi/g)
			Average	Range (low/high)	
January–March	Upstream	2	2.1	0.0 – 6.4	0.13
	Downstream	3	2.7	.0 – 4.2	.6
April–June	Upstream	3	5.6	.42–15.4	3.7
	Downstream	3	1.0	.03– 2.05	1.2
July–September	Upstream	3	1.75	1.51– 2.23	1.6
	Downstream	3	2.30	1.85– 2.54	1.9
September–December	Upstream	[a] 1	2.4	2.4 – 2.4	1.9
	Downstream	[b] 2	2.6	2.19– 2.95	1.9

[a] No sample taken in December as creek bottom was frozen.
[b] Sample data not available for October—malfunction of required counting room equipment.

2. Portsmouth Area Gaseous Diffusion Plant[3] July–December 1969

Goodyear Atomic Corporation
Piketon, Ohio

The separation of uranium isotopes by the gaseous diffusion process presents control problems similar to any chemical process using toxic solvents and extraction solutions. Natural uranium and thorium-234 are the most likely radionuclides to be released to the environment by the Portsmouth Area Gaseous Diffusion Plant. To verify the effectiveness of plant controls, environmental monitoring is conducted for evidence of alpha-particle, beta-particle, and gamma-ray emitters.

Air samples are collected monthly at 21 sites located from 1 to 6 miles from the plant as shown in figure 2. Monthly water samples are collected at 13 stations within 5 miles of the plant.

For July–December 1969, the alpha radioactivity in water, alpha and beta-gamma radioactivity in air, and background exposure increased over the first half of 1969 values. The beta-gamma radioactivity in water for the July–December period decreased compared with the January–June values.

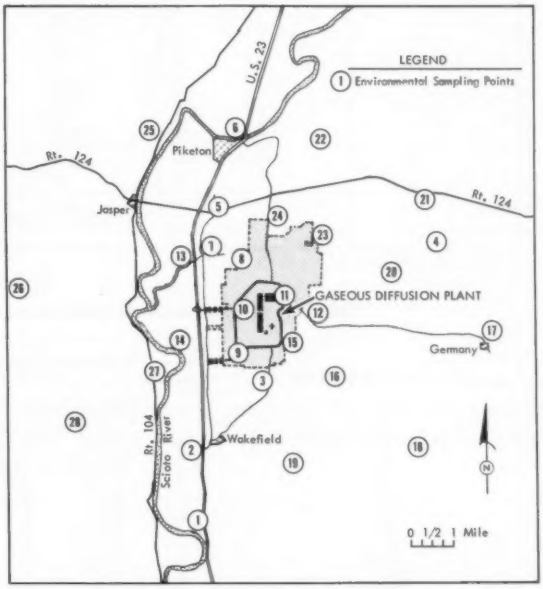

Figure 2. Sampling locations, Portsmouth Area Gaseous Diffusion Plant

[3] Data summarized from B. Kalman and S. H. Hulett, "Environmental Radiation Levels and Concentrations, Second Half 1969" (March 6, 1970).

Table 5. Radioactivity in air, Portsmouth Plant, July–December 1969

Location	Number of samples	Alpha radioactivity concentration (pCi/m³)			Average as a percent of AEC standards[a]	Beta–gamma radioactivity concentration (pCi/m³)			Average as a percent of AEC standards[a]
		High	Low	Average		High	Low	Average	
2	6	0.4	<0.1	0.1	5	1.0	<0.1	0.4	0.04
3	6	.9	<.1	.2	10	1.4	<.1	.6	.06
4	6	.3	<.1	.1	5	1.2	<.1	.6	.06
6	6	.9	<.1	.2	10	1.2	<.1	.4	.04
9	6	.1	<.1	<.1	<5	1.7	<.1	.4	.04
12	6	.6	<.1	.2	10	.8	<.1	.5	.05
13	6	.4	<.1	.1	5	.9	<.1	.3	.03
15	6	.2	<.1	<.1	<5	.8	<.1	.5	.05
16	5	.8	.2	.4	20	2.0	.2	.9	.09
17	5	1.3	<.1	.3	15	1.4	.2	.6	.06
18	5	.1	<.1	<.1	<5	1.1	<.1	.3	.03
19	5	.1	<.1	<.1	<5	.8	<.1	.2	.02
20	6	.6	<.1	.2	10	.6	<.1	.3	.03
21	6	1.4	<.1	.3	15	2.5	<.1	.6	.06
22	5	.2	<.1	.1	5	.5	<.1	.3	.03
23	6	.3	<.1	<.1	<5	.4	<.1	<.1	<.01
24	6	.4	<.1	.1	5	1.0	<.1	.3	.03
25	6	.2	<.1	<.1	<5	.6	<.1	.2	.02
26	6	2.4	.3	.8	40	2.4	<.1	1.1	.11
27	5	1.2	<.1	.5	25	2.5	<.1	.9	.09
28	6	1.4	<.1	.6	30	2.1	<.1	.8	.08
Average	120	2.4	<0.1	0.2	10	2.5	<0.1	0.5	0.05

[a] The AEC radiation protection standard for alpha radioactivity in air—2 pCi/m³, beta–gamma radioactivity—1 nCi/m³; sensitivity of analysis of both alpha and beta radioactivity is 0.01 mrem/h.

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Table 6. Radioactivity in water, Portsmouth Plant, July–December 1969

Location	Number of samples	Alpha radioactivity concentration (pCi/m³)			Average as a percent of AEC standards[a]	Beta–gamma radioactivity concentration (pCi/m³)			Average as a percent of AEC standards[a]
		High	Low	Average		High	Low	Average	
1	6	9.0	<0.5	4.2	0.02	<14.0	<14.0	<14.0	<0.07
2	6	4.5	1.4	3.0	.02	31.5	<14.0	<14.0	< .07
3	6	2.7	< .5	.9	<.01	<14.0	<14.0	<14.0	< .07
4	6	3.2	< .5	1.0	<.01	<14.0	<14.0	<14.0	< .07
5	6	18.0	< .5	3.6	.02	45.0	<14.0	<14.0	< .07
6	6	4.5	.5	2.5	.01	31.5	<14.0	<14.0	< .07
7	6	230	76.5	144	.72	522	22.5	206	1.03
8	6	288	90.0	146	.73	261	<14.0	163	.82
10	6	104	.5	18.0	.09	410	<14.0	72.9	.36
11	6	369	18.0	195	.98	599	54.0	220	1.10
12	6	2.7	< .5	1.0	<.01	36.0	<14.0	<14.0	< .07
13	6	126	18.0	50.9	.25	202	<14.0	82.4	.41
14	6	13.5	.5	6.3	.03	54.0	<14.0	14.9	.07
Average	78	369	0.5	44.4	0.22	598	<14.0	58.4	0.29

[a] The AEC radiation protection standard for alpha and beta radioactivity in water—20 nCi/liter; sensitivity of analysis, alpha radioactivity—0.5 pCi/liter; beta radioactivity—14.0 pCi/liter.

Table 7. Background exposure rates, Portsmouth Plant, July–December 1969

Location	Number of samples	Background rate[a] (μrem/h)			Background average rate extrapolated to 3-foot level (μrem/h)	Average as percentage of dose limit rate[b]
		High	Low	Average		
2	6	14.0	11.7	12.7	8.5	14.9
3	6	12.9	9.3	11.7	7.8	13.7
4	6	14.0	11.2	12.3	8.2	14.4
6	6	15.7	10.9	13.5	9.0	15.8
9	6	20.7	12.1	14.2	9.5	16.6
12	6	14.8	11.2	12.4	8.3	14.5
13	6	13.3	10.9	12.1	8.1	14.2
15	6	14.5	10.2	11.6	7.7	13.4
16	6	14.0	11.7	12.3	8.2	14.4
17	6	16.2	10.5	13.4	8.9	15.6
18	6	12.6	10.0	11.1	7.4	13.0
19	6	13.6	11.4	12.2	8.1	14.2
20	6	16.2	11.9	14.2	9.5	16.6
21	6	20.9	11.2	14.5	9.7	17.0
22	6	14.3	10.4	12.3	8.2	14.4
23	6	15.2	11.4	13.2	8.8	15.4
24	6	14.0	11.9	13.1	8.7	15.2
25	6	15.9	10.5	12.5	8.3	14.5
26	6	14.0	10.7	12.4	8.3	14.5
27	6	15.0	12.4	14.0	9.3	16.3
28	6	15.5	10.7	12.2	8.1	14.2
Average	126	20.9	9.3	12.8	8.5	14.9

[a] Open-shield geiger tube one foot above ground.
[b] The AEC radiation protection standard for external beta–gamma radioactivity—0.5 rem/a (approx. 600 μrad/h) limit of sensitivity—0.1 μrem/h.

Penetrating background dose rates for 1969 were slightly lower when compared with the calendar year 1968 values. In the calibrations, it is assumed that all of the dose rates are attributable to plant operations. As in the past, the offsite and onsite patterns are very much alike in form and intensity with no significant differences between the average values. From the onsite and offsite intensities, it is evident that the plant operations have not added appreciably to the general background radiation.

Average alpha and beta-gamma radioactivity concentrations in air are summarized in table 5. Table 6 contains the average alpha and beta-gamma radioactivity concentrations in water. The external gamma-ray levels, measured at the air

Table 8. Comparison of average concentrations Portsmouth, 1969

Type of monitoring	Percent of AEC standard[a]			
	Calendar year 1968	January–June 1969	July–December 1969	Calendar year 1969
Air:				
Alpha radioactivity	<5.0	<5.0	[b] 10.1	5.7
Beta-gamma radioactivity	0.02	.02	.05	.03
Water:				
Alpha radioactivity	.28	[c] .20	.22	.20
Beta-gamma radioactivity	.43	.38	.29	.32
Background exposure extrapolated to 3 feet above ground level	18.3	13.5	14.9	14.3

[a] See footnote (a) of tables 5 and 6, footnote (b) of table 7.
[b] This value was influenced by three high values in August, however, all values were considerably below the AEC standards. There is no explanation for the high result.
[c] This value was erroneously reported as 0.02 in the previous report.

sampling locations shown in figure 2, are summarized in table 7. The overall average concentrations and background exposure rates for 1968 and January–June 1969 and July–December 1969 are presented in table 8 as percent of standards.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	November 1969
January–June 1969	April 1970

Reported Nuclear Detonations, September 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission announced that on September 6, 1970 the United States recorded seismic signals, presumably from a Soviet underground nuclear expolosion. The signals originated at about 2400 e.d.t., September 5, from the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20–200 kilotons.

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Errata

In the June 1970 issue of *Radiological Health Data and Reports* the following typographical errors occurred in the article "Zirconium-95 in Utah Vegetation Produced During the 1966 Growing Season":

1. page 279, column 2, 11th line—should read "and milk *from* farms which showed. . ."
2. page 279, column 2, 14th line—should read ". . . vegetation during the time should have *been* indicated by sharply . . ."
3. page 280, column 1, 2nd line—"reference 12" should be "reference 11."

Editors note: After publication of this article it was discovered that two announced nuclear tests had been omitted from table 1, page 278. Both tests were detonated on June 15, 1966 at the Nevada Test Site. One test had a yield of 20–200 kilotons. The second test had a yield of less than 20 kilotons and was reported to have vented with minor levels of radioactivity being detected offsite.

In the August 1970 issue an error occurred in table 3 of the article entitled "Disposal of Radioactive Waste from U.S. Naval Nuclear-powered Ships and Their Support Facilities, 1969." Please make the following corrections in table 3 on page 376:

Facility	Number of samples with concentration of cobalt-60:
	>100 pCi/cm²
Pearl Harbor, Hawaii; Naval Shipyard and base	1
Apra Harbor, Guam	0

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip then for their files.

SOME MEASUREMENTS ON RADIOACTIVITY IN SWEDEN CAUSED BY NUCLEAR TEST EXPLOSIONS. *Attilio Magi, Jan Olof Snihs, and Gun Astri Swedjemark. Radiological Health Data and Reports, Vol. 11, October 1970,* pp. 487–509.

Data on environmental radioactivity levels in Sweden during the period 1959–1968 are summarized. Emphasis is placed on gamma radiation from the ground and concentrations of cesium-137 and strontium-90 in some foodstuffs of special interest, such as dairy milk and reindeer meat. Various empirical correlations between the concentrations of radioactivity in milk and meat and those found in precipitation are discussed; such correlations may be used in planning environmental sampling programs. The radiation dose contribution to the population due to fallout is assessed.

KEYWORDS: Body burdens, calcium, cesium-137, fallout, milk, potassium, precipitation, radioactivity, reindeer, strontium-90, Sweden.

ENVIRONMENTAL SURVEY OF URANIUM MILL TAILINGS PILE, MONUMENT VALLEY, ARIZ. *Robert N. Snelling. Radiological Health Data and Reports, Vol. 11, October 1970,* pp. 511–517.

At the request of the Navajo Tribal Council through the Public Health Service Division of Indian Health at Window Rock, Ariz., an environmental radiological survey was conducted on the Foote Mineral Company's uranium tailings pile, Monument Valley, Ariz., in May 1968. The purpose of the survey was to identify any radiation hazards which might exist and recommend methods for their control. The survey included evaluation of external gamma radiation, airborne radioactivity, and waterborne radioactivity.

The results of the survey indicate that existing radiation levels do not exceed recommended exposure limits. However, to minimize the possibility of increased activity from weather conditions different from those existing during the survey, it was recommended that the mill tailings be stabilized against wind erosion. Otherwise, periodic monitoring will be necessary in the future.

KEYWORDS: Air, Arizona, environmental survey, exposure limits, gamma radiation, mill tailings, uranium, water.

RESULTS OF A STUDY OF COLOR TELEVISION SET ASSEMBLY AND REPAIR WORKERS X-RAY SAFETY: *Stanley D. Savic. Radiological Health Data and Reports, Vol. 11, October 1970,* pp. 519–525.

A study was conducted to determine the degree of exposure of television set assemblers and repairmen to low levels of low energy x radiation. Two independent companies supplied the x-ray film badges on a biweekly basis. In addition, some television repairmen were also asked to wear thermoluminescent (TLD) ring badges so that the degree of hand exposure to x rays could be determined. In two large service shops, detailed records were also kept of the number and models of television receivers which were serviced. The largest total exposure recorded by film badges worn by any repairman during the one and a half year duration of the survey, was 34 mR. During that same time, no other badge showed any radiation, and therefore we assume that this one film was inadvertently exposured to heat or some other element. In a later survey, there were a few scattered hand exposure readings ranging from 10 to 70 mR for TLD rings which were continuously worn over a 3-month period. These readings were also suspected to be false because they were not repeatable with the same individuals and because hundreds of other TLD rings registered no dosage. During the 8-months duration of the factory assemblers' survey, over half a million color television receivers were produced by the 1,000 monitored employees. Not a single film badge worn in the factory assemblers' survey showed any radiation. We conclude that occupational x-radiation exposure of television repairmen and assemblers is virtually nonexistent.

KEYWORDS: Color television, film badges, hand exposure, safety, TV repairmen, TV set assemblers, x radiation.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ELEVATED LEVELS OF CESIUM-137 IN COMMON MUSHROOMS (*Agaricaceae*) WITH POSSIBLE RELATIONSHIP TO HIGH LEVELS OF CESIUM- 37 IN WHITETAIL DEER, 1968–1969. *Wallace Johnson and Chester L. Nayfield.* Radiological Health Data Reports, Vol. 11, October 1970, pp. 527–531.

High levels of cesium-137 exist in game animals of the southeastern United States. The highest levels ranging from 250 to 152,940 picocuries per kilogram have been found in muscle tissue of the Whitetail deer. Levels in Florida range from 10 to 100 times those encountered in Alabama. An important factor in the diet of these animals in Florida is the common gill mushroom, *Agaricaceae*. Examination of these fungi revealed cesium-137 levels higher by an order of magnitude than levels in vegetation. Similar concentrations of potassium-40 do not occur, indicating a selective effect.

KEYWORDS: *Agaricaceae*, cesium-137, deer, Florida, game animals, mushrooms

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